Mississippian Carbonates and Siliciclastics in Western Illinois

Geological Field Trip 6: April 24–25, 1999

Zakaria Lasemi, Rodney D. Norby, Joseph A. Devera, Bruce W. Fouke, Hannes E. Leetaru, and F. Brett Denny

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Cover photo *Alby Quarry, Alton, Illinois, showing the Warsaw Formation (bottom) and the Salem, St. Louis, and Ste. Genevieve Limestones in the highwall (photo by Z. Lasemi and R.D. Norby).*

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FIGURES

Stratigraphy, Paleoenvironments, and Sequence Stratigraphic Implications of the Middle Mississippian Carbonates in Western Illinois—*Zakaria Lasemi and Rodney D. Norby*

On this field trip, we will examine rocks representing the Meramecian Series (upper half of the Valmeyeran), which is the most widely exposed Mississippian series in the St. Louis metro area on both sides of the Mississippi River (fig. 1). This part of the guidebook provides general background for discussion and interpretation of the features that will be seen at various field trip stops. The Mississippian units that will be visited include the Warsaw Formation and the Salem, St. Louis, and Ste. Genevieve Limestones. The trip focuses on the stratigraphy and depositional facies of these units as seen in roadcuts and quarries in the St. Louis metro area of Illinois. We will discuss litho- and biostratigraphic relationships, examine oolitic and bioclastic grainstone shoals and shoaling-upward cycles, and analyze sequence stratigraphic relationships. An overview of the structural and geological settings, the sequence stratigraphy of the Aux Vases Sandstone, and a brief discussion of the diagenetic history are presented in following sections.

Boundaries between the middle Mississippian carbonate and siliciclastic units have been drawn differently by various workers. The inconsistencies have resulted in confusion and some misinterpretation of stratigraphic relationships. Currently we are studying the regional stratigraphy and depositional facies of the middle Mississippian units in western Illinois. Our lithostratigraphic and biostratigraphic data, integrated with published information, provide a useful framework for understanding regional stratigraphic and sequence stratigraphic relationships among these units.

We have recognized a number of key stratigraphic horizons among the Mississippian units in the field trip area and adjacent regions. These horizons include: (1) a discontinuity surface between the lower and upper Warsaw, (2) an unconformity at the Salem–St. Louis Limestone boundary, (3) a conodont faunal break accompanied by a change in lithofacies between the lower and upper St. Louis, (4) the "Lost River Chert" zone, a widespread bryozoan-rich chert and thinly bedded, bryozoan-rich lime mudstone and wackestone, and (5) the facies change accompanied by a change in the conodont fauna at the St. Louis–Ste. Genevieve Limestone boundary. During this field trip, we will discuss the significance of these horizons for understanding the middle Mississippian stratigraphy in the area and for interpreting the sequence stratigraphic relationships.

The Mississippian carbonates are economically important units in the Illinois Basin. They are excellent sources of construction aggregates and high-calcium limestones, and contain hydrocarbon reservoirs in Illinois and adjacent states. A better understanding of stratigraphic and sequence stratigraphic relationships will help to delineate lateral and vertical variations in the thickness and quality of aggregate resources and factors that control hydrocarbon reservoir development.

Mississippian Units in Western Illinois

This section discusses the litho- and biostratigraphy of the Mississippian units that will be visited in the field trip area. On the basis of new information from our ongoing studies in the area, we have revised the stratigraphic boundaries between several Mississippian units, thus elucidating some of the sequence stratigraphic relationships. However, because of space limitations, sequence stratigraphy will not be covered in detail in this guidebook, but will be discussed at various field trip stops.

Warsaw Formation The oldest formation that will be encountered during this trip is the Warsaw Formation (Hall 1857) or Warsaw Shale (fig. 1). It occurs in western and southwestern Illinois, southeastern Iowa, and eastern Missouri. Rocks equivalent in age to the Warsaw are present in western Missouri, Kansas, Nebraska, and throughout the Illinois Basin (Lasemi et al. 1998). Facies analysis and biostratigraphic data suggest that the Warsaw is divisible into an upper and a lower

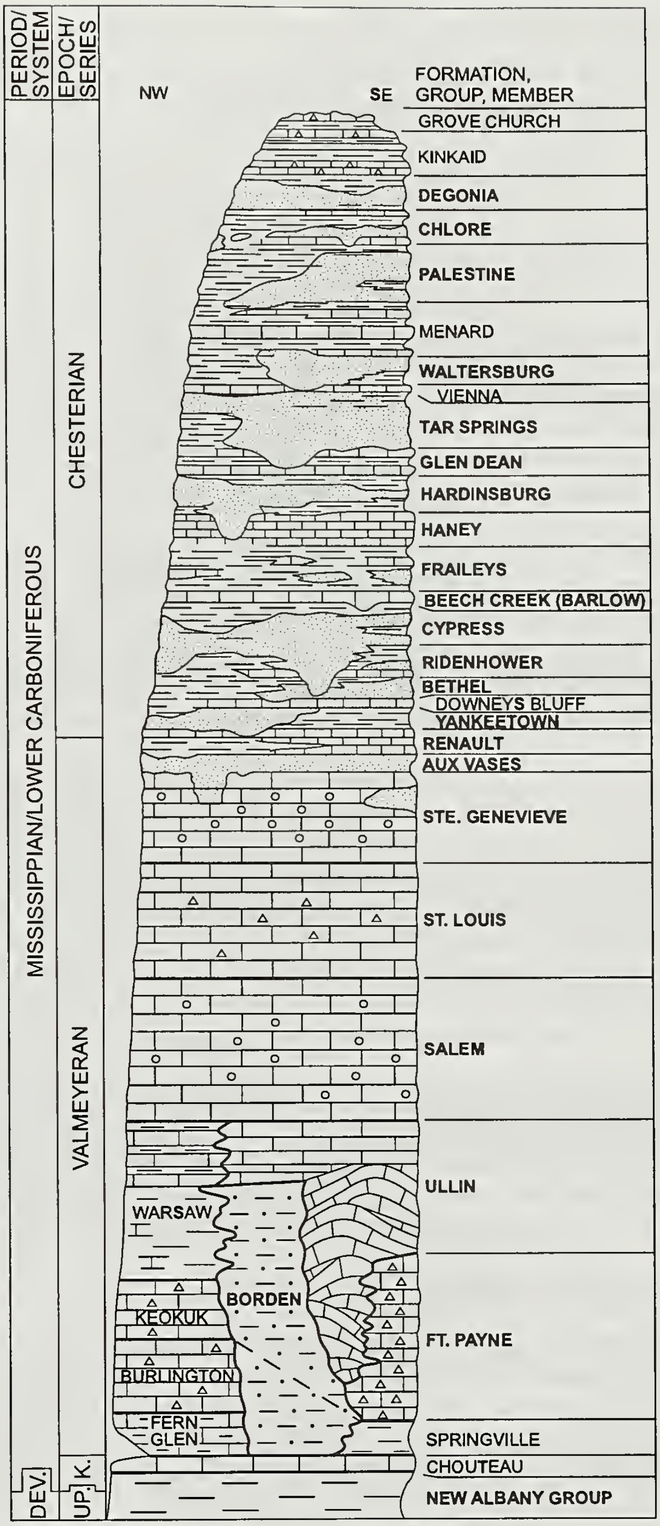

Figure 1 Generalized stratigraphic column (Mississippian) for Illinois. Formations or members that contain hydrocarbon pay zones are shown in bold type. Abbreviations: Devonian (DEV.), Upper Devonian (UP.), and Kinderhookian (K.). Variable vertical scale (modified from Lasemi et al. 1994).

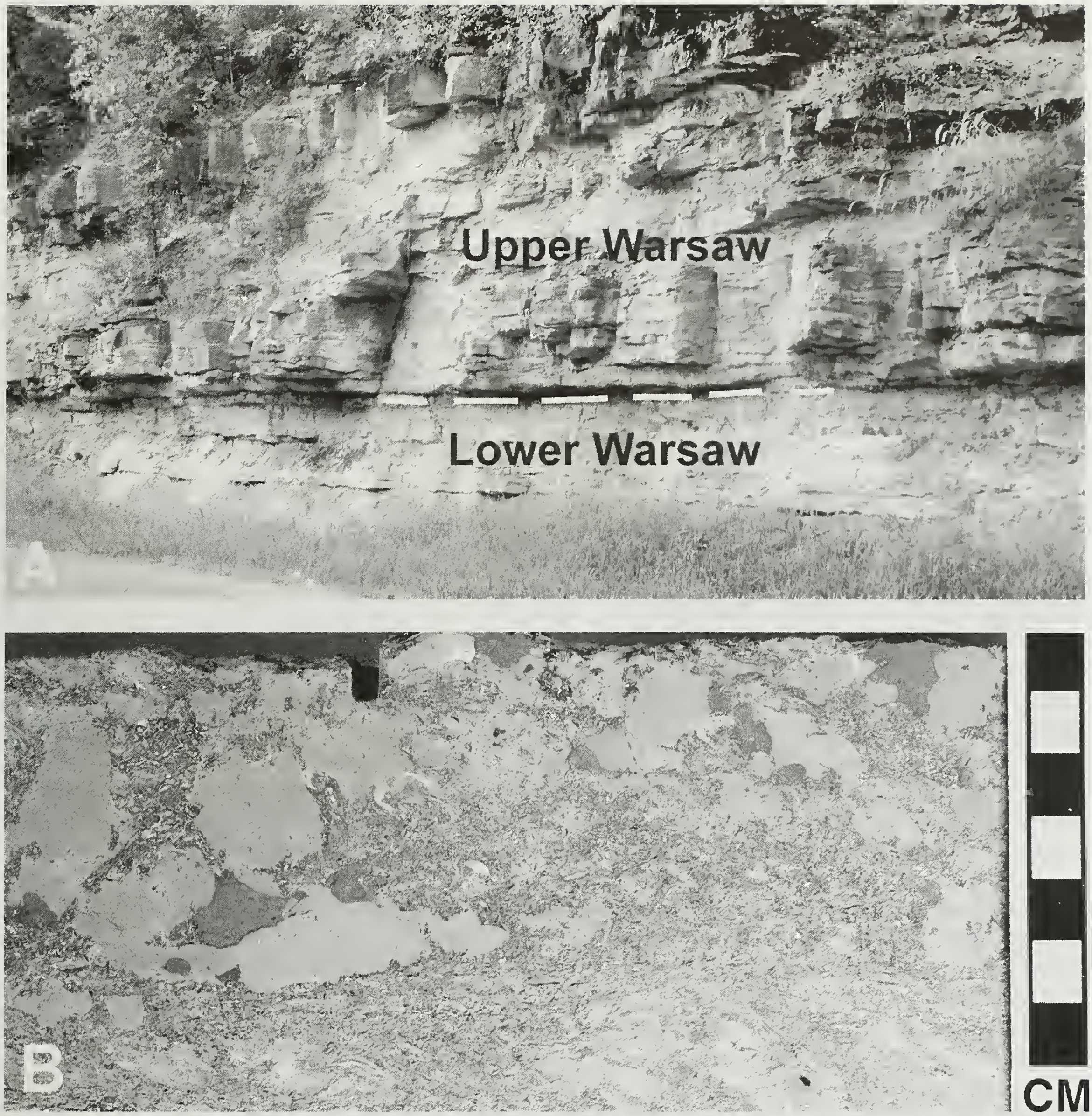

Figure 2 (A) Lower and upper Warsaw Formation, Beltrees Road section, NE NE SW Sec. 13, T6N, R11W, Jersey County, Illinois, Elsah 7.5-minute quadrangle. (B) An intraclastic, pyritic, and phosphatic horizon occurs near the lower–upper Warsaw boundary (dashed line in A).

interval (Kammer et al. 1990, this study). The lower part of the Warsaw is primarily a shale, whereas limestone and, in some areas, dolomite constitute a significant portion of the upper part of the Warsaw (fig. 2 and Stop 1).

Lower–upper Warsaw boundary The contact between the upper and lower Warsaw has been drawn at different horizons by different authors (Hall 1857, Hall and Whitney 1858, Ulrich 1904, Weller 1908, Van Tuyl 1925). Recent studies (Kammer et al. 1990) have characterized the Warsaw both lithologically and paleontologically, and redefined its relationship to the Osagean–Meramecian boundary. Kammer et al. (1990) basically employed Van Tuyl's (1925) concept of a lower and upper Warsaw, except that the lower–upper Warsaw boundary was adjusted upward to the top of Hall's (1857) "Magnesium limestone" rather than to its base. The separation into lower and upper Warsaw essentially places the thick shales, dolomitic shales, and argillaceous dolomites (often allied with the upper Keokuk) into the lower Warsaw, and the poor to moderately sorted, bioclastic

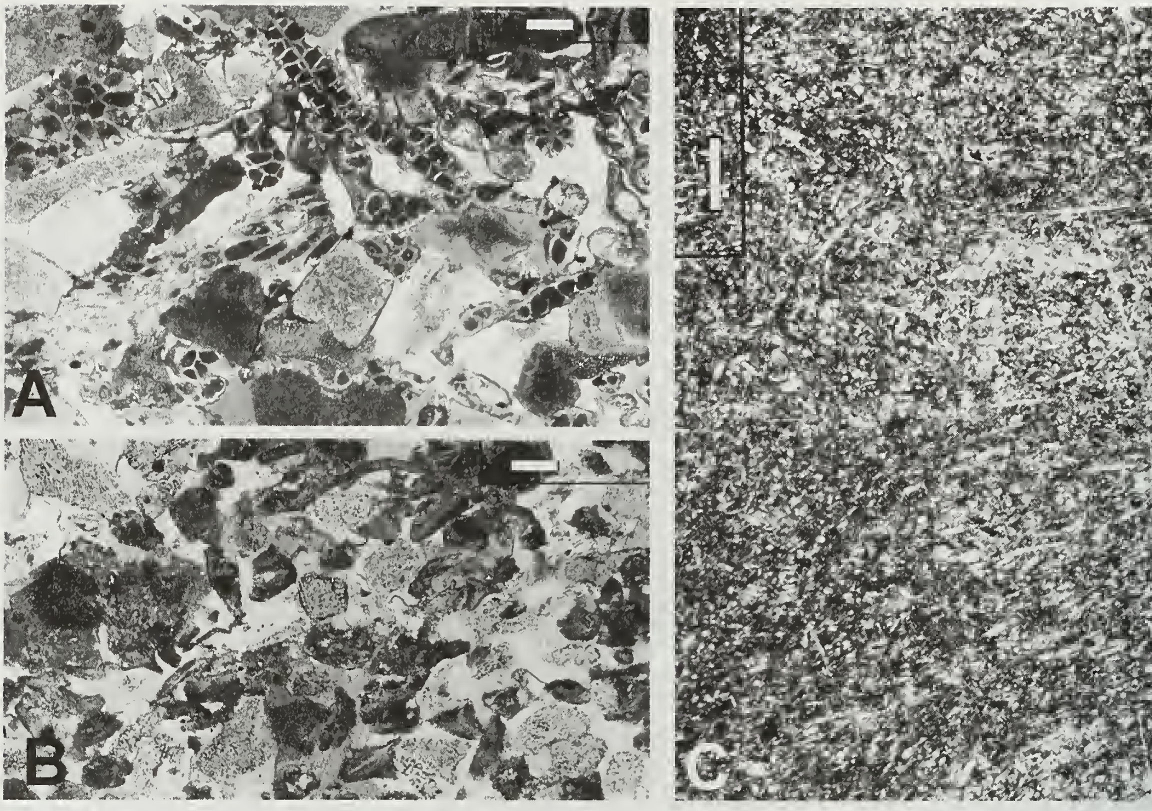

Figure 3 Thin section photomicrographs (cross-polarized light) from Columbia roadcut (Stop 1). (A) Upper Warsaw (unit 21, fig. 20a); note poorly sorted echinoderm and bryozoan fragments. (B) Moderately sorted, crinoidal-bryozoan grainstone of the Salem (unit 3, fig. 20a). (C) "Fults" Member of the Salem (unit 12, fig. 20a), note common sponge spicules (needle-shaped particles). Bar scales = 0.5 mm.

grainstones and shaley limestones into the upper Warsaw. This general scenario extends from the type Warsaw area in Hancock County, Illinois, to the St. Louis metro area and appears to extend farther south to the Ste. Genevieve, Missouri, area (Kammer et al. 1990). The paleontologic change that occurs at the contact between the lower and upper Warsaw is chronostratigraphically significant, and Kammer et al. (1990) used this faunal change to mark the Osagean–Meramecian Series boundary.

Our ongoing study of the Warsaw in the outcrop and subsurface has revealed a disconformity surface (condensed horizon) near the lithologic and faunal change suggested by Kammer et al. (1990). This horizon occurs at or near the top of the shale-dominated interval of the lower Warsaw and is characterized by an intraclastic and phosphatic limestone with abundant pyrite and some glauconite (fig. 2B). This apparent disconformity surface can be traced from the type Warsaw area in Hancock County, western Illinois, south to the St. Louis metro area, and north into southeastern Iowa.

Prior to 1966, the Warsaw Formation included the limestone unit that underlies the Salem in the deeper parts of the basin. Lineback (1966) renamed the "Warsaw" of southern Illinois, the Ullin Limestone and restricted the term Warsaw to the mixed carbonate-shale units (Warsaw Formation) in western Illinois. The upper Warsaw is similar and equivalent, at least in part, to the upper Ullin Limestone in southern Illinois (Kammer et al. 1990, Lasemi et al. 1998). The Ullin (fig. 1) is a light-colored, crinoidal-bryozoan grainstone that ranges in thickness between 150 and 800 feet. At the Columbia roadcut (Stop 1), the limestone that is believed to be part of the upper Warsaw (Kammer et al. 1990, and our studies) was assigned to the Ullin by Collinson et al. (1979). Because this limestone is closely associated and interfingers with the shaley interval of the Warsaw, we believe the term upper Warsaw, rather than Ullin, is more appropriate.

Depositional environment Like the upper Ullin Limestone of southern Illinois, the upper Warsaw is primarily a poorly sorted and poorly rounded grainstone dominated by remains of echinoderms (primarily crinoids) and bryozoans (fig. 3A). Poor sorting and poor rounding of grains and the common presence of hummocky cross stratification in the upper Warsaw carbonates suggest rapid deposition, perhaps in a storm-dominated environment. Similar conditions have been interpreted for deposition of the upper Ullin Limestone to the east in the Illinois Basin (Lasemi et al. 1994, 1998). Crinoidal-bryozoan bioherms, which were common during deposition of the Ullin Limestone (Lasemi et al. 1994, 1998), also were apparently present in some areas during deposition of the upper Warsaw (Lasemi and Smith 1999) and provided skeletal material for development of storm-deposited carbonate sand shoals. Both the Ullin and Warsaw grade into a better sorted and rounded, partly oolitic to pseudo-oolitic, grainstone in the uppermost part. The Ullin/upper Warsaw deposition ended with brief exposure and was followed by a regional transgression that resulted in deposition of the argillaceous, spiculitic, and siliceous limestone of the lower Salem (Lasemi et al. 1998).

Salem Limestone The Salem Limestone (Cumings 1901) is a bioclastic, partly oolitic to pseudo-oolitic limestone up to 500 feet thick in the central part of the Illinois Basin in southern Illinois (Cluff 1984). The unit generally ranges between 60 and 100 feet thick at the margins of the basin in western Illinois. The Salem (fig. 1) overlies the Ullin Limestone in southern Illinois and the Warsaw Formation in western and southwestern Illinois. It is overlain by the St. Louis Limestone throughout the basin. In some areas in northwestern and west-central Illinois and southeastern Iowa, a fine-grained, greenish gray calcareous sandstone, the Sonora Sandstone (Keyes 1895), underlies and grades laterally into the Salem (Atherton et al. 1975).

The Salem Limestone in the St. Louis metro east area consists of a few cyclic sequences of shoaling-upward grainstone and tidally influenced lime mudstone (Lasemi et al. 1996, 1997). The grainstones are for the most part better sorted and rounded (fig. 3B) than the crinoidal-bryozoan grainstones in the upper Warsaw and Ullin (fig. 3A). The Salem is a bioclastic, partly pseudo-oolitic to oolitic limestone that contains abundant forams, peloids, and some green algae (Baxter 1960, Baxter and Brenckle 1982, Cluff 1984). The lower part of the Salem is a cherty, spiculitic, argillaceous and dolomitic limestone (fig. 3C) that regionally overlies the Ullin/upper Warsaw in the Illinois Basin. In southwestern Illinois and Ste. Genevieve County, Missouri (see inside back cover), the Salem is mainly a crinoidal, bryozoan, peloidal grainstone in the lower part (fig. 4A) and an oolitic to pseudo-oolitic, foraminiferal grainstone in the upper part (fig. 4B). Our petrographic data indicate that the lower part of the Salem in these areas is lithologically similar to the entire Salem in the St. Louis metro east area.

The Salem Limestone has been the subject of several studies. Major studies of the Salem in the subsurface of the Illinois Basin include Lineback (1972), Keller and Becker (1980), Cluff and Lineback (1981), and Cluff (1984). Baxter (1960, 1965) studied the general facies and economic importance of the Salem Limestone in the western Illinois outcrop belt. He subdivided the Salem in Monroe, Randolph, and St. Clair Counties, southwestern Illinois, into four members, which in ascending order are (1) the Kidd, a crinoidal-bryozoan grainstone, (2) the Fults, an argillaceous, cherty, laminated and silty limestone with some bioclastic limestone, (3) the Chalfin, largely a fine-grained limestone that is partly oolitic to pseudo-oolitic and pelletal, and partly sublithographic and brecciated, and (4) the Rocher, a fine to coarse, bioclastic, partly oolitic grainstone with microfauna similar to those of the Chalfin and lower St. Louis. Because of lithologic similarities to the Ullin Limestone, Lineback (1966) assigned most of the Kidd Member to the upper Ullin Limestone (Harrodsburg Member). We basically concur with Lineback (1966), but currently believe that all of the Kidd should be included with the Ullin Limestone of southern Illinois or the upper Warsaw in the St. Louis–Prairie du Rocher–Ste. Genevieve area. The Kidd represents the last phase of Ullin/upper Warsaw deposition that was ended by a regional transgression marked by relatively

Figure 4 Thin section photomicrographs (cross-polarized light) of the Salem Limestone from Ste. Genevieve County, Missouri. (A) Lower Salem intraclastic, crinoidal-bryozoan grainstone; bar scale = 0.25 mm. (B) Upper Salem foraminiferal, oolitic grainstone; bar scale = 0.5 mm.

deep water facies of the lower Salem ("Fults" and its lateral equivalents). We have found it is difficult to recognize the Salem members as defined by Baxter (1960) beyond the type sections in southwestern Illinois. These members appear to us to be depositional facies, which roughly correspond to shoaling-upward cycles commonly seen within the Salem in the subsurface (Cluff 1984) in southern Illinois and in the outcrop belts in western Illinois (Lasemi et al. 1996, 1997).

Depositional environment Cluff (1984) investigated the depositional facies of the Salem in the subsurface. He recognized up to four shoaling-upward cycles within the Salem in the southern Illinois subsurface (fig. 5). He suggested that towards the margins of the basin (including western Illinois), the Salem grades into a fine-grained, restricted facies that generally lacked the typical shoaling-upward cycles seen in the subsurface. However, we have identified similar, but thinner cycles within the Salem in the outcrop belts in western Illinois (Lasemi et al. 1996, 1997). The number of cycles in the Salem has recently been used as a predictive tool in assessing limestone quality and reserves in several quarries in western Illinois (Lasemi et al. 1996, 1997, Wolf 1997). Because the cycles are thinner here, they cannot be easily recognized at the resolution provided by the standard petroleum industry geophysical logs.

In western Illinois, a typical cycle consists of (1) a very thin, transgressive conglomeratic unit (fig. 6), (2) a relatively thick shoal facies consisting of a dense, high-calcium, bioclastic grainstone, and (3) a thin intertidal facies consisting of argillaceous lime mudstone and dolomite (fig. 6). In places, the intertidal facies contains tidal and stromatolitic laminations. A bioclastic wackestone and lime mudstone representing an open marine subtidal facies may underlie the grainstone shoal facies in some areas. In geophysical logs (fig. 5), the argillaceous tidal flat facies of the cycle shows a positive spontaneous potential (SP) and high gamma ray responses, whereas the clean grainstone shoal facies of the cycle shows negative SP and very low gamma ray responses. Each Salem cycle represents a shoaling-upward (shallowing-upward) sequence formed as a result of fluctuations in the relative sea level or lateral migrations of contemporaneous environments within a single depositional system (fig. 7).

Ullin/Warsaw–Salem boundary The contact between the Warsaw Formation and the overlying Salem Limestone generally has been considered gradational. However, published data and new information based on our work suggest that an unconformity marks the boundary between the Warsaw and Salem in the outcrop belt. Weller and Sutton (1940) reported that the Salem, or the laterally equivalent Sonora Sandstone (Keyes 1895), unconformably overlies the Warsaw Formation in northwestern Illinois and southeastern Iowa. In Adams County, Illinois, a possible unconformity marked by a basal conglomerate occurs in the middle of the carbonates overlying the lower Warsaw shale (Weller and Sutton 1940, p. 813). Weller and Sutton (1940) suggested that this unconformity was equivalent to the unconformity beneath the Salem in southeastern Iowa. A major brecciated and conglomeratic horizon also overlies the upper Warsaw crinoidal-bryozoan grainstone (now a fossil moldic dolomite) in a quarry in southeastern Iowa (Lasemi and Smith 1999). In central Pike County, Illinois, major erosion apparently removed the Warsaw and underlying Keokuk prior to deposition of the Salem, and the Salem rests directly on the Burlington Limestone (Coryell 1919, p. 93).

We have identified a potential subaerial exposure surface at the upper Warsaw–Salem boundary in an abandoned quarry in Schuyler County, Illinois. This surface is characterized by an oxidized, undulatory surface overlain by a brecciated interval with possible laminated crusts. In some areas in western and southern Illinois and in Ste. Genevieve County, Missouri, the contact appears to be a discontinuity surface marked by a hardground (fig. 8). Elsewhere, the upper Warsaw–Salem boundary is marked by a change in lithofacies from that of a shallow water limestone in the upper Warsaw, to a silty, spiculitic, *Zoophycos*-bearing, argillaceous deeper water limestone at the base of the Salem (Stop 1; fig. 3C). A similar, relatively deep water facies that we interpret to be equivalent to the Somerset Shale at the base of the Salem in Indiana and Kentucky (Benson 1976) overlies the Ullin in much of the southern Illinois subsurface (Lasemi et al. 1998).

St. Louis Limestone The St. Louis Limestone (fig. 1; Englemann 1847, Ulrich 1904) in the Illinois Basin consists predominantly of fenestral, pelletal and peloidal limestone; algal limestone (oncolite and stromatolite); bioclastic wackestone to packstone with some grainstone; microcrystalline dolomite; gypsum and anhydrite; limestone breccia beds; chert; and siliceous limestone. Fine-grained, lithographic limestone can be quite common in some intervals (Atherton et al. 1975), but

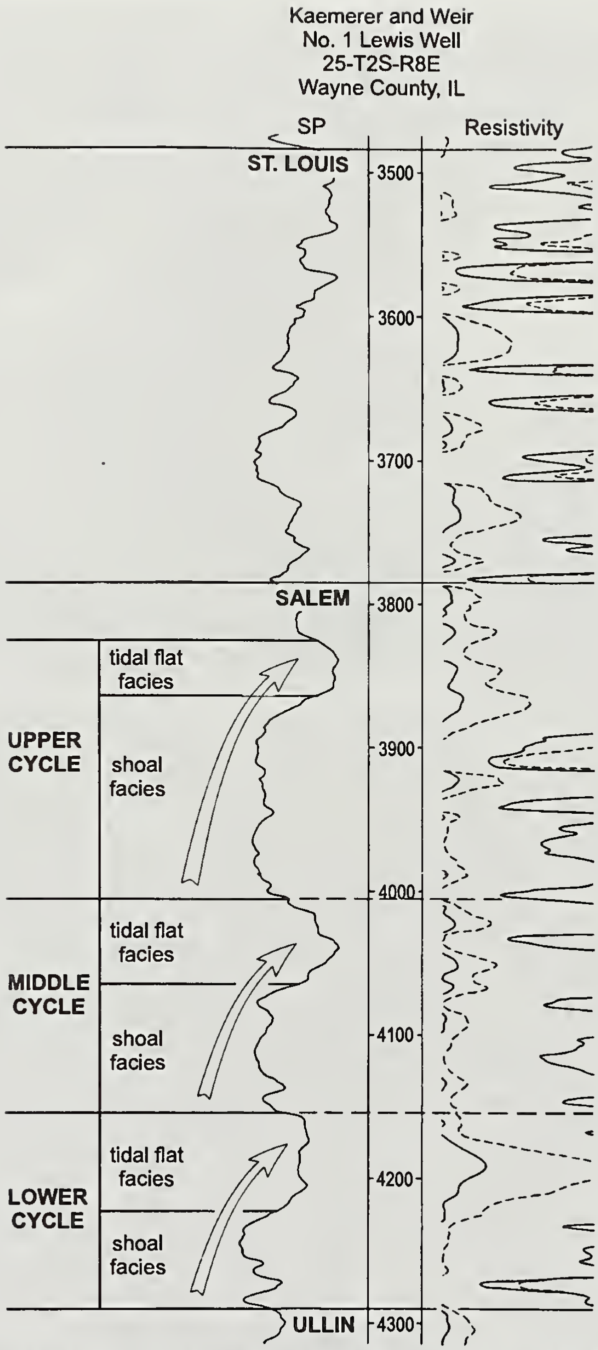

Figure 5 Geophysical log of shoaling-upward cycles in the Salem Limestone (modified from Cluff 1984).

is not necessarily the dominant lithology. Gypsum and anhydrite are commonly present in the lower part of the St. Louis in the subsurface (Krumbein 1951, McGregor 1954, Saxby and Lamar, 1957, McGrain and Helton 1964, Dever and McGrain, 1969, Diaby and Carozzi 1984), but are generally confined to shelf areas at the margin of the basin. In and close to the outcrop belts, no gypsum or anhydrite beds have been found, but several breccia beds that occur in the lower part of the St. Louis have been related to collapse of the overlying limestone layers after dissolution of gypsum and anhydrite beds (Collinson et al. 1954, Collinson and Swann 1958).

Figure 6 Section of the Salem Limestone from Columbia Quarry Company's Plant No. 1, NE Sec. 10, T1S, R10W, St. Clair County, Illinois, Columbia 7.5-minute quadrangle, showing part of the intertidal-supratidal facies of an individual shoaling-upward cycle, overlain by the grainstone shoal facies of the next cycle. Note intraclasts above hammer head representing a transgressive surface at the base of the grainstone shoal facies.

Depositional environment Pinsak (1957, p. 23–24) divided the St. Louis of Indiana into two parts on the basis of lithology. The lower part is composed of dense, brown carbonaceous limestone that alternates with units of gypsum and anhydrite and interbeds of black, gray, and greenish shale. This lithology indicates a period of restricted water circulation during deposition of the lower St. Louis Limestone. The upper part of the St. Louis is micritic, pelletal, and skeletal limestone, which represents a return to a more open marine environment. Similar lithology with a restricted marine limestone facies in the lower part and an open marine facies in the upper part also characterizes the unit equivalent to the St. Louis in southeastern Iowa (Croton Member of the "St. Louis"; Witzke et al. 1990) and southeastern Kentucky (Pohl 1970). Microfacies analysis of the St. Louis Limestone in Illinois, Indiana, and Kentucky (Diaby and Carozzi 1984) also revealed that a widespread restrictive environment prevailed during the early stages of St. Louis deposition.

In the St. Louis metro east area, the lower and upper parts of the St. Louis Limestone are also lithologically distinct, and the boundary at which the change in facies occurs corresponds to the

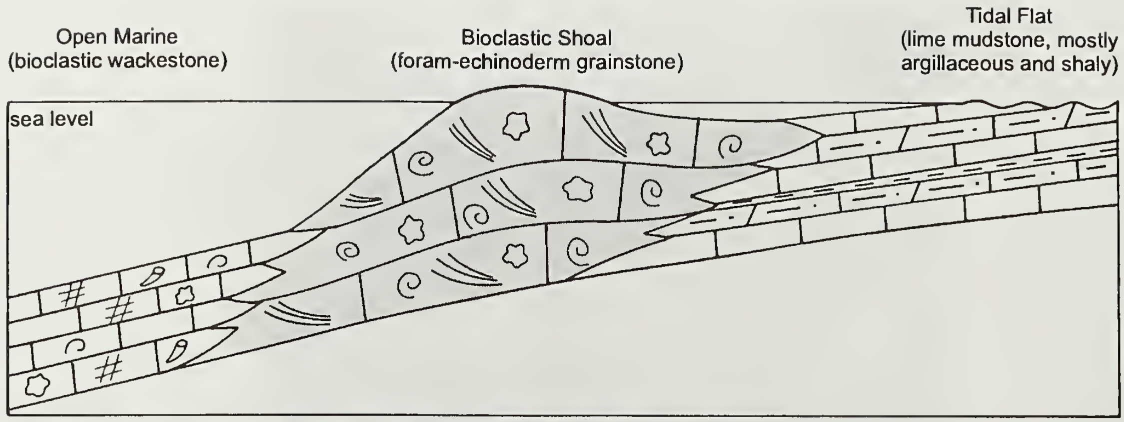

Figure 7 Idealized depositional model for an individual Salem cycle.

conodont break reported by Rexroad and Collinson (1963; see following section). In these areas, we have found that the lower St. Louis is characterized by a nearshore restricted marine facies consisting of pelleted and fenestral lime mudstone, algal limestone (oncolitic and stromatolitic; fig. 9A), collapsed breccia beds, and microcrystalline dolomite. Mudcracks are also present in some of the lime mudstone facies (fig. 9B). Southward from Waterloo, the restricted marine facies of the St. Louis grades into an open marine facies. Farther south in parts of Monroe and Randolph Counties, southwestern Illinois, and in Ste. Genevieve County, Missouri, the restricted marine facies of the lower St. Louis grades into an open marine, shallow shelf facies characterized by oolitic to pseudo-oolitic, foraminiferal grainstone of the upper Salem (fig. 4B), which was interpreted by Weller and St. Clair (1928) and Baxter and Brenckle (1982) to be equivalent to the lower St. Louis in the St. Louis metro area. We interpret the upper Salem in these areas to represent a ramp margin grainstone belt behind which a restricted marine lagoon and tidal flat environment developed, where the restricted marine facies of the lower St. Louis was deposited. The rocks of the ramp margin grainstone belt grade seaward farther south into siliceous, spiculitic, cherty lime mudstone and wackestone in the deeper part of the basin.

The upper St. Louis in the field trip area is characterized by bioclastic wackestone to packstone, lime mudstone, and some bioclastic-peloidal grainstone. These rocks, which reflect a return to normal marine conditions, form a transgressive facies that onlaps the upper Salem and lower St. Louis from southern Monroe and part of Randolph Counties, Illinois, and Ste. Genevieve County, Missouri, northward into the St. Louis metro area. Onset of this transgression ended the restricted conditions that existed during the deposition of the lower part of the St. Louis.

Lower–upper St. Louis boundary A two-part subdivision of the St. Louis Limestone was first implied by Weller and St. Clair (1928) and later by Collinson et al. (1954) and Collinson and Swann (1958). A distinct conodont break marks the boundary between the lower and upper St. Louis (Rexroad and Collinson 1963). The regional conodont *Taphrognathus–Apatognathus* Assemblage Zone (unrevised) that typifies the Salem and the lower part of the St. Louis changes to the *Apatognathus scalenus–Cavusgnathus* Assemblage Zone (unrevised) in the upper part of the St. Louis (Rexroad and Collinson 1963, 1965). The latter zone ends at the end of St. Louis deposition and aids in the determination of the St. Louis–Ste. Genevieve boundary (Norby and Lasemi 1999). In the St. Louis metro east area, the upper and lower St. Louis boundary has been placed a short distance above the main breccia in the middle of the St. Louis (Collinson and Swann 1958). Southward from the Columbia area, the breccia beds are not present, and the distinction between the lower and upper St. Louis is less clear. However, we have identified a light greenish gray, argillaceous limestone and/or shaley bed (up to 4 feet thick) that occurs at or just above the lower–upper St. Louis boundary in the St. Louis metro east area (see Stops 2, 4, and 6). This bed is a key marker that can be traced from the Alton area to as far south as Ste. Genevieve County, Missouri.

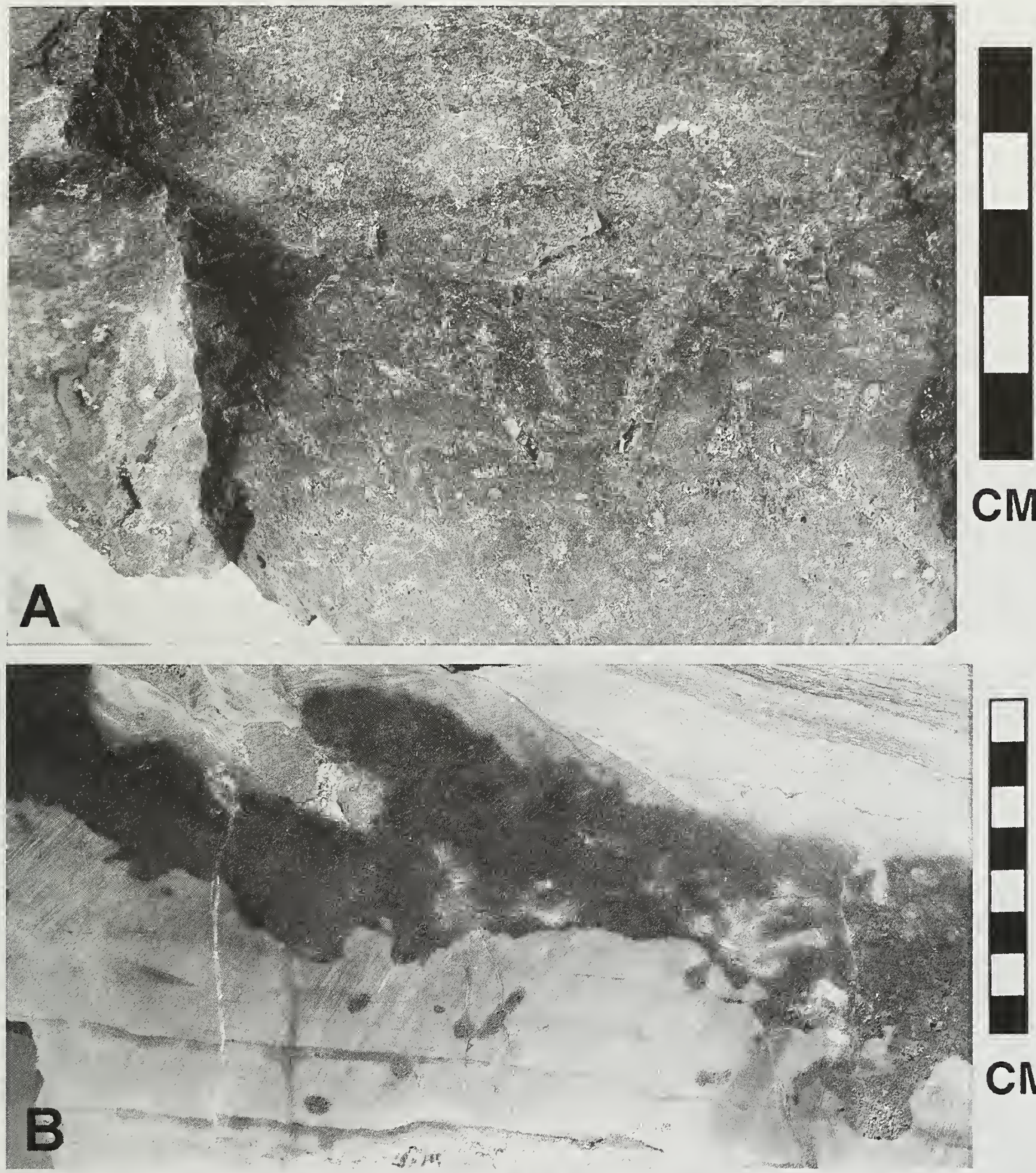

Figure 8 Bored discontinuity surface (hardground) at the Warsaw–Salem boundary. (A) Tower Rock Stone Company quarry, Sec. 7, T38N, R9E, Ste. Genevieve County, Missouri, Prairie du Rocher 7.5-minute quadrangle. (B) Lohr quarry, SE Sec. 5, T6N, R10W, Madison County, Illinois, Alton 7.5-minute quadrangle.

Salem–St. Louis boundary The position of the contact between the Salem and the overlying St. Louis has been a subject of controversy. The base of a cherty lime mudstone and/or the appearance of the first bioclastic grainstone have been inconsistently used to separate the Salem from the St. Louis, especially in the subsurface. Numerous workers (Weller and St. Clair 1928, Weller et al. 1948, Collinson et al. 1954, Collinson and Swann 1958, and Baxter and Brenckle 1982) have shown, on the basis of lithologic character and micro- and macrofossils, that the upper part of the Salem in the Ste. Genevieve area, Missouri, and in southwestern Illinois is equivalent to the lower part of the St. Louis in the St. Louis metro area. On the basis of electric log cross sections, Lineback (1972) suggested that the upper part of the Salem on the northwest slope of the Illinois Basin (Monroe and Randolph Counties) lithologically graded laterally into the lower part of the St. Louis

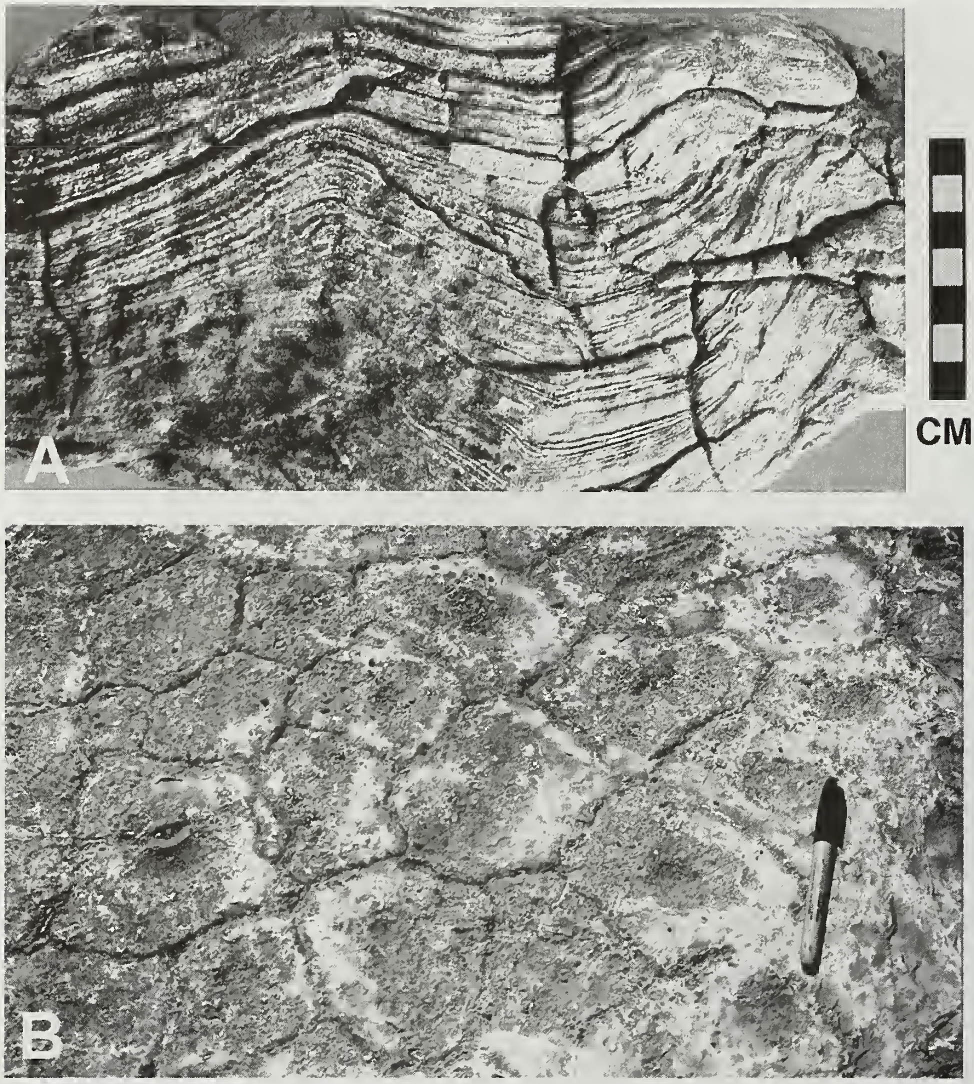

Figure 9 (A) Stromatolitic laminations, lower St. Louis, type Warsaw locality, NW NW Sec. 10, T4N, R9W, Warsaw 7.5-minute quadrangle, Hancock County, Illinois. (B) Mudcracks, lower St. Louis, Columbia Quarry Company's Plant No. 1, NE Sec. 10, T1S, R10W, St. Clair County, Illinois, Columbia 7.5-minute quadrangle; 5-inch pen for scale.

in the St. Louis metro area (particularly in Madison County, Illinois). Cluff (1984) suggested that the grainstone facies of the Salem graded northward into a fine-grained tidal flat facies similar to that in the St. Louis Limestone.

New information from our ongoing study tends to support the above interpretations regarding lateral gradation between the upper Salem and lower St. Louis. Our data indicate, however, that the lower St. Louis is equivalent to the upper Salem only south of Waterloo, Illinois, in the Renault–Prairie du Rocher–Ste. Genevieve area. Conodont data indicate that the lower–upper St. Louis boundary, which occurs in the middle of the St. Louis Limestone in the St. Louis metro area, occurs at the Salem–St. Louis boundary in the Ste. Genevieve area, which corroborates foraminiferal data by Baxter and Brenckle (1982). We have also identified a persistent unconformity characterized by a karstic or erosional surface at the Salem–St. Louis contact in the St. Louis metro area (fig. 10 and Stop 2). On the basis of foraminiferal ranges, Baxter and Brenckle (1982) also suggested a possible local hiatus between the Salem and St. Louis in the metro area; an unconformity at a similar stratigraphic position was also reported by Weller and Sutton (1940, p. 815) from northwestern

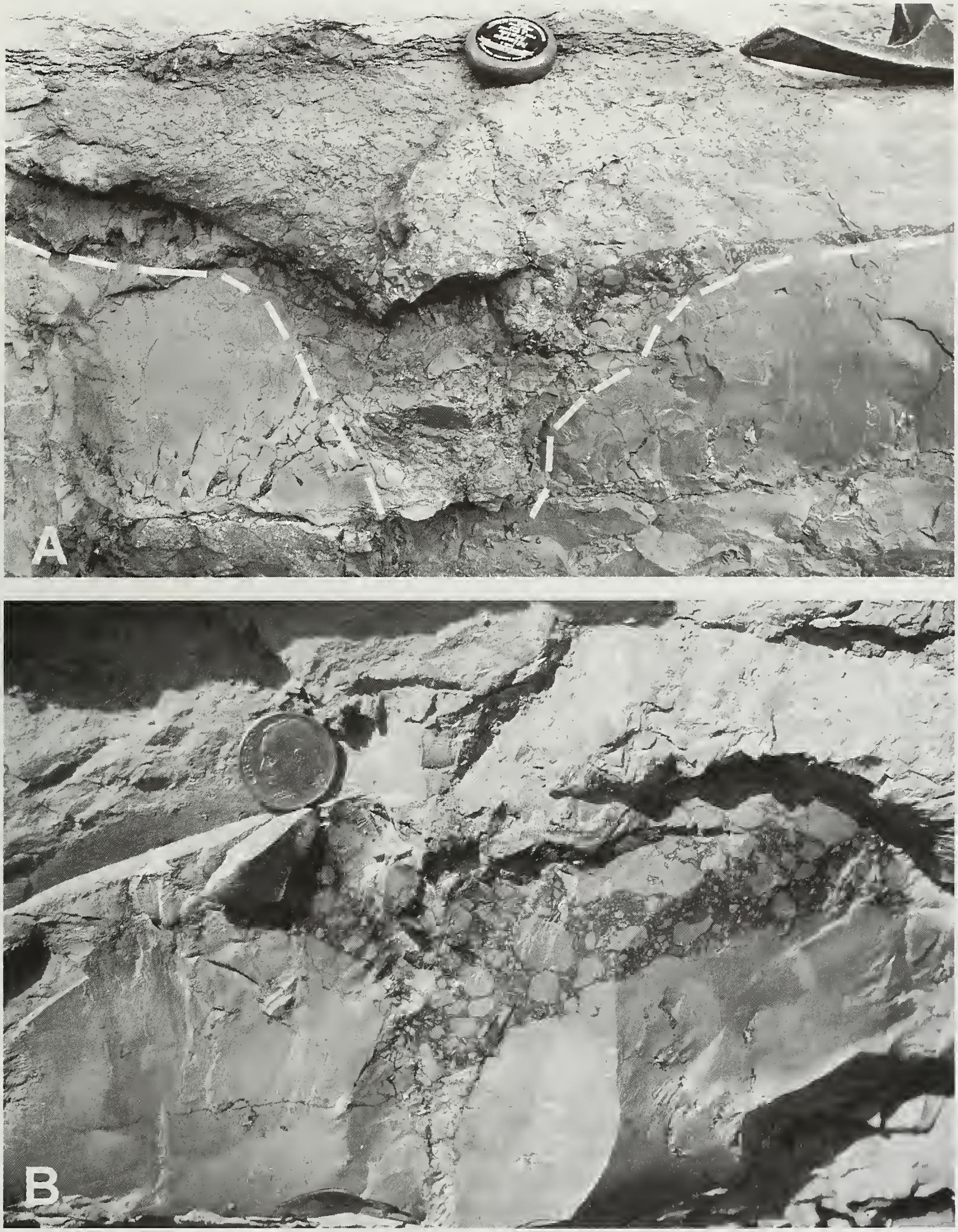

Figure 10 Paleokarstic surface at the Salem–St. Louis boundary, Waterloo quarry (Stop 2). (A) An overall view; note prominent solution channel (dashed line) at the center of the photo; 1.3-inch bottle cap for scale. (B) Close view of the brecciated surface and a solution fissure; 0.7-inch coin for scale.

Illinois. We have found an unconformity within the Salem in a core from near Renault, Monroe County, Illinois. Petrographically, the rock below this unconformity is similar to the Salem in the St. Louis metro area. The rock above the unconformity consists of shoaling-upward, oolitic, peloidal, foraminiferal grainstone (fig. 4B). We believe that this unconformity, which lies within the Salem in the Renault–Prairie du Rocher–Ste. Genevieve area (see inside back cover), is equivalent to the unconformity we have seen at the Salem–St. Louis boundary in the St. Louis metro area. If correct, these correlations indicate that the entire Salem in the St. Louis metro area is equivalent to the lower Salem, and the lower St. Louis in the metro area is equivalent to the upper Salem in the Renault–Prairie du Rocher–Ste. Genevieve area—a conclusion supported by the biostratigraphic data.

Ste. Genevieve Limestone The Ste. Genevieve Limestone (fig. 1; Shumard 1860) occurs only sporadically at the top of some bluff sections in the St. Louis metro east area (Collinson et al. 1954, Atherton et al. 1975). Here the limestone is typically an arenaceous, oolitic grainstone, with varying amounts of fossiliferous shaley limestone, dolomitic limestone, lime mudstone, and some bioclastic grainstone interbeds (see Stops 4, 6, and 7). Elsewhere in the basin, the Ste. Genevieve Limestone contains well developed oolitic grainstone deposited as irregular banks, linear sand bars, and tidal bar belts (Carr 1973, Choquette and Steinen 1980, Cluff 1984). The Ste. Genevieve Limestone has been one of the most prolific hydrocarbon producers in the Illinois Basin.

St. Louis–Ste. Genevieve boundary As an aid in recognizing the St. Louis–Ste. Genevieve boundary in Indiana, Rexroad et al. 1990 utilized the Lost River Chert Bed, which generally appears from 5 to 10 feet below the top of the St. Louis. The Lost River Chert Bed (Elrod 1899) is a distinct and regionally widespread stratigraphic marker that occurs in the uppermost part of the St. Louis Limestone around the basin (Pohl 1970, Woodson 1982, Rexroad et al. 1990). The Lost River Chert Bed is cream to red to black, generally irregular to blocky chert, with abundant bryozoans and some brachiopods and corals. A sharp change in the conodont fauna also occurs at the upper boundary of the Lost River Chert Bed. In Illinois, Indiana, and Kentucky, the upper St. Louis fauna includes *Synclydognathus geminus*, whereas the Ste. Genevieve includes *Hindeodus cristulus* (Collinson et al. 1971, Rexroad et al. 1990). This abrupt change, covering a wide geographic area, implies a major hiatus at the St. Louis–Ste. Genevieve boundary (Rexroad et al. 1990). Along with conodont and other lithologic criteria, the Lost River Chert Bed is a very reliable marker that has helped establish the position of the St. Louis–Ste. Genevieve boundary in these areas.

In the St. Louis metro area, we have identified a chert-bearing interval at about the same horizon near the top of the St. Louis (see Stops 2, 4, 6, and 7). This zone is a thin-bedded, bryozoan-rich lime mudstone to wackestone that has some bioclastic packstone to grainstone. It generally contains from one to several chert beds, including one that we believe to be equivalent to the Lost River Chert Bed. The Lost River Chert Bed has not formally been recognized in the St. Louis metro area, and until we can verify specific beds, we have informally called the entire interval the "Lost River Chert" zone (Norby and Lasemi 1999).

The "Lost River Chert" zone is irregular in thickness in the St. Louis metro area, possibly due to truncation at the St. Louis–Ste. Genevieve unconformity. The unconformity at the St. Louis–Ste. Genevieve boundary has also been reported from Ste. Genevieve County, Missouri (Weller and St. Clair 1928). In places in the Ste. Genevieve area, the St. Louis beds are truncated, and a conglomeratic horizon occurs at the St. Louis–Ste. Genevieve boundary. Elsewhere, solution fissures that occur at the St. Louis surface are filled with sediments from the overlying Ste. Genevieve (Weller and St. Clair 1928). In the Alton bluff section (Stop 7), Collinson et al. (1954) also reported the presence of vertical fissures several feet deep at the top of the bryozoan beds (= "Lost River Chert" zone) that were filled with sediment from the overlying Ste. Genevieve Limestone.

Conodonts indicative of the upper St. Louis are common in the "Lost River Chert" zone and are succeeded by Ste. Genevieve conodonts in beds above the "Lost River Chert" zone. In addition to the change in the conodont fauna, the contact here marks a change from a clean, bioclastic lime mudstone and wackestone in the "Lost River Chert" zone below, to shaley, silty, argillaceous, sandy, oncolitic limestone above. In the St. Louis metro area, the top of the "Lost River Chert" zone marks the contact between the St. Louis and the Ste. Genevieve Limestone.

Previously, in western Illinois, the St. Louis–Ste. Genevieve boundary was not well defined and was placed within a 35-foot "transition zone," where the lithologic and paleontologic characteristics of the two formations appeared to be mixed (Collinson et al. 1954). The occurrence of the "Lost River Chert" zone near the top of this "transition zone," the change in conodont fauna, and revised macrofossil ranges all show that most of the "transition zone" belongs to the St. Louis with only a few feet of it assigned to the Ste. Genevieve (discussed further at Stop 7).

Economic Significance

The middle Mississippian carbonates are important sources of crushed stone and high-calcium limestone in western Illinois and adjacent areas. Porous and permeable intervals within some of these units form prolific hydrocarbon reservoirs in the Illinois Basin. Some of these units (e.g., the Salem and Ullin) are excellent sources for high-calcium limestone used for lime production, environmental remediation, and other industrial applications. Construction and maintenance of roads and buildings relies heavily on the local availability of inexpensive, high-quality stone resources (Lasemi et. al. 1996, 1997). The St. Louis metro area contains significant amounts of stone reserves, but these are shrinking because of rapid development and urbanization.

Detailed descriptions of local and regional facies, and regional stratigraphic analyses currently underway in the area are important in understanding lateral and vertical variations in the thickness and quality of aggregate resources. Facies analyses are useful in predicting the quality and reserves of minable stone. For example, we have used the cyclicity (shoaling-upward cycles) revealed by facies analysis within the Salem Limestone to predict the quality and remaining reserves in several active quarries in western Illinois (Lasemi et al. 1996, 1997). Accurate prediction of stone reserves and quality will optimize output, reduce exploration cost, and help environmentally responsible development and expansion of existing mines and quarries.

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STRUCTURAL GEOLOGY OF THE METRO-EAST ST. LOUIS AREA—*Joseph A. Devera and F. Brett Denny*

A structurally complex monoclinal feature, the Lincoln Fold and Cap au Grès Faulted Flexure, affects the Paleozoic rocks in the Metro-East St. Louis area (fig. 11). The Cap au Grès in the northern part of the Metro-East area trends eastward but bends to the southeast at Deer Lick Hollow (fig. 12) near the confluence of the Illinois and Mississippi Rivers. Southeast of Deer Lick Hollow, the structure is concealed beneath the Mississippi River alluvium, and the Mississippi takes a sharp turn eastward, apparently to follow the Cap au Grès Faulted Flexure. It returns to its general southward direction of flow at the eastern extent of this feature (fig. 11). At its west end, the Cap au Grès merges with a northwest-trending anticline, the Lincoln Fold. The term Cap au Grès is normally applied only to the steeply dipping and faulted southwest limb of the Lincoln Fold. The Florissant Dome is a medial structure between the Cap au Grès and the Waterloo-Dupo Anticline (fig. 12). The Florissant feature bends to the south-southeast and is probably disrupted by the St. Louis Fault Zone (Frank 1948). The structure continues to the south-southeast, where it is called the Waterloo-Dupo Anticline. The whole faulted fold complex is monoclinal with the south and west limbs as the steep sides. Early workers thought that each of the above features was a separate structure (Rubey 1952, Cole 1961). In order to maintain a balanced structural offset, however, Harrison (1993) interpreted these structures as parts of a single system.

Geologic History

The geology of western Illinois has been influenced by the Ozark Dome, the Sangamon Arch, the Sparta Shelf, the Lincoln Fold or Cap au Grès Faulted Flexure, and the Waterloo-Dupo Anticline. The Ozark Dome probably has been an upland surface since Early Cambrian with intermittent Paleozoic seaway inundations. It is composed primarily of granite and rhyolite and forms a high of Precambrian rocks to the south named the St. Francois Mountains. Cambrian and Ordovician units in Missouri and Illinois thin toward the St. Francois Mountains, which indicates that this feature has had positive relief since at least Early Cambrian time. The Sparta Shelf also was a positive surface during Cambrian sedimentation because the Cambrian Mt. Simon Formation is thin or absent in this area (Nelson 1995). During Late Ordovician, the Ozark Dome may have undergone slight uplift as shown by deposition of the Thebes Sandstone in southwestern Illinois and Missouri. Ordovician rocks in the area are diverse and include sandstones, carbonates, siltstones, and shales.

Silurian sedimentation was dominated by carbonates and shales to the south, but in the Metro-East area the Silurian rocks have been altered to dolomites. By Middle to Late Silurian, pinnacle reefs were forming along the margins of the shelf area and separating deeper water deposits from the shallow environment. Silurian sediments, while absent in western Madison County, thicken quickly to the east and attain a thickness of over 500 feet in eastern Madison County. Northwest of Grafton in western Madison County, several feet of Middle Devonian Cedar Valley Limestone can be observed at a few isolated outcrops. These are the only Devonian rocks exposed in the area.

The lower Mississippian rocks (Kinderhookian and Valmeyeran) unconformably overlie Devonian through Ordovician rocks. Late Mississippian through early Pennsylvanian was a time of major deformation in the area, when the Cap au Grès Faulted Flexure and the Waterloo-Dupo Anticline were active. The structures have steep dips on the south or west limbs and gentle dips of less than 4° on their north or east limbs. Most researchers agree that these structures were produced by reverse faulting of a Precambrian basement block and draping of the sedimentary cover (Rubey 1952, Tikrity 1968, Nelson and Lumm 1985). At the end the Mississippian, a fall in sea level produced a subaerial exposure across Illinois. In the Belleville area, recent mapping has detected a local erosional surface with nearly 70 feet of relief on the top of the Mississippian rocks. Lows on the erosional surface were filled with sands and silts as valley-fill sequences during the Pennsylvanian.

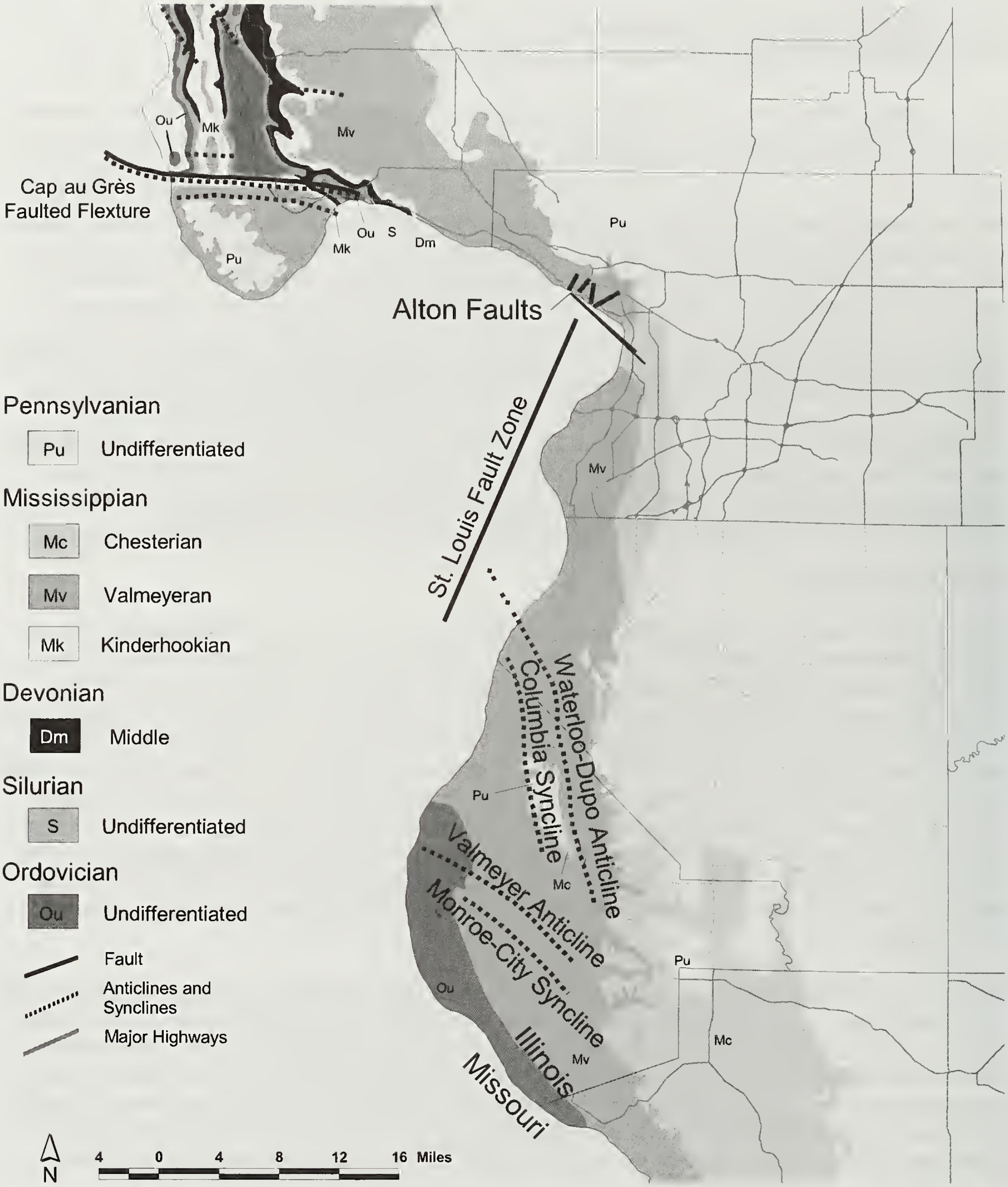

Figure 11 Geologic map of the field trip area in western Illinois. Bedrock geology is modified from Illinois Geographic Information System, Volume 1, May 1996.

Tectonic Relationships

Ozark Dome The Ozark Dome is a Precambrian high that has influenced the deposition of sediments throughout the area. Early Paleozoic rocks thin toward the dome, which indicates its prolonged existence as a structural prominence. While this dome was undoubtedly a structural high, there is little evidence that it was ever a major source of clastic material to the Illinois Basin. The Ozark Dome was an area of low relief during much of Paleozoic history and was completely buried or nearly covered by Middle Devonian sediments. Alkalic igneous intrusions of Devonian age

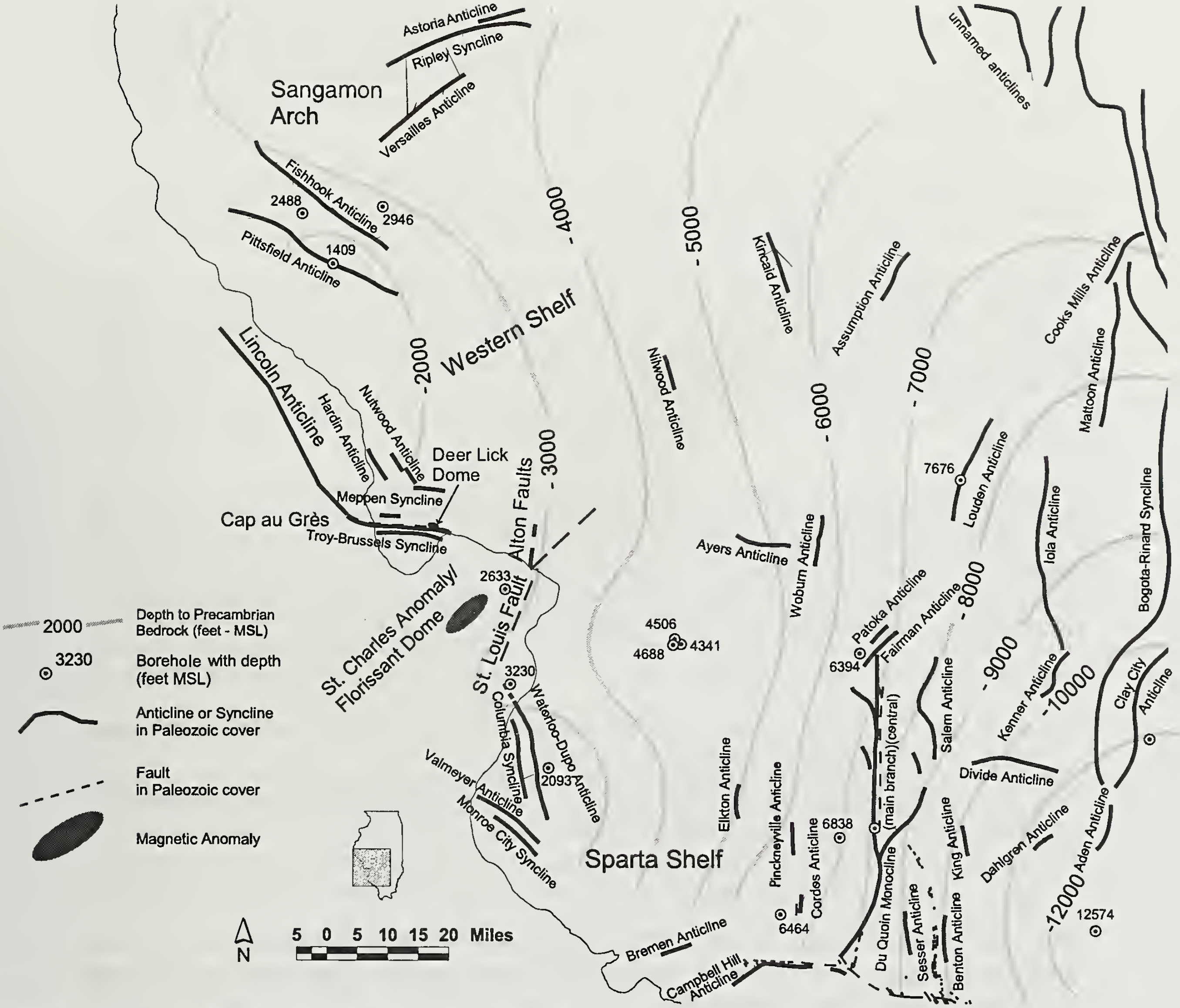

Figure 12 Structural features of west and west-central Illinois.

occur in southeast Missouri within the domal complex and indicate that the dome may have been rising at that time. The few wells that reach the Precambrian basement in the area indicate relatively steeper drops in basement elevations eastward than northeastward into the Illinois Basin. Two wells, cited by Harrison (1993), penetrated the Precambrian basement in Missouri at –3,445 feet and –2,649 feet mean sea level. In Illinois, several wells have penetrated the basement surface (fig. 12).

Lincoln Fold/Cap au Grès Faulted Flexure The most plausible explanation for the Cap au Grès feature was offered by Rubey (1952), Nelson and Lumm (1985), Harrison (1993), and Nelson (1995). All authors discuss the possibility of a deep-seated reverse fault in the Precambrian basement. The Cap au Grès resembles monoclinal drape folds found on the Colorado Plateau that formed in sedimentary strata overlying reactivated basement faults (Harrison 1993). Nelson and Lumm (1985) compared the Cap au Grès Faulted Flexure with Laramide monoclines in the Rocky Mountains and Colorado Plateau, where folds in sedimentary cover overlie faults in the Precambrian crystalline basement (Nelson 1985). The authors concur that the primary displacement along the structure is probably related to deep-seated reverse movement along a Precambrian basement block.

The timing of the Lincoln Fold/Cap au Grès event is weakly constrained by broad stratigraphic relationships. We suggest that the structure was active starting in post–Middle Devonian time and continuing sporadically through the earliest Pennsylvanian. No evidence for Tertiary or younger faulting suggested by Rubey (1952) has been observed during recent Illinois State Geological Survey mapping efforts in this area.

Waterloo-Dupo Anticline The asymmetrical Waterloo-Dupo anticline has a steep westward-dipping limb with an axis that trends slightly west of north. In places, the western limb has dips greater than 45°, but the eastern limb has dips of only 2° to 4°. The structural style of this anticline is similar to the Salem, Louden, and La Salle Anticlines in Illinois and is probably a result of drape folding over a buried basement fault (Nelson 1995). Thinning of Silurian and Devonian units indicates that the basement fault was active during the Late Devonian. The major deformation took place prior to the Pennsylvanian because Desmoinesian units (Pennsylvanian) unconformably overlie Chesterian units (Mississippian).

Summary

The general alignment of tectonic structures parallel to the basement structure contours (fig. 12) suggests a connection between these Paleozoic structures and basement faulting. Locally, some small anticlines and synclines may have formed by differential compaction and drape over buried Precambrian bedrock highs, similar to the drape structures located over Silurian pinnacle reefs, but the larger structures clearly resulted from regional compressional stress. Ongoing geologic mapping in the area is defining the regional structural history of the area.

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INCISED VALLEYS INTO THE STE. GENEVIEVE LIMESTONE—*Hannes E. Leetaru*

The top of the Mississippian carbonate section in Illinois is a regional unconformity or sequence boundary with paleotopographic relief of up to 100 ft (Leetaru 1997). Typically, the Aux Vases Sandstone directly overlies the Ste. Genevieve Limestone (fig. 1). In parts of Monroe County, Illinois, the underlying limestone is part of the St. Louis Limestone based on conodont age dating (Rodney D. Norby, Illinois State Geological Survey, personal communication, 1997).

A clear representation of the three-dimensional morphology of the Aux Vases Sandstone can be developed by integrating both outcrop and subsurface data. A subtle eastward elongation of sandstone bodies is shown by a sandstone isolith map of the Aux Vases (fig. 13). The trends of the sandstone bodies parallel elongate areas where the Spar Mountain Sandstone was eroded (fig. 14); these areas are designated as North Valley, Central Valley, and South Valley (Leetaru 1997). The best defined of these features, Central Valley (fig. 14), is up to 20 miles wide and extends 40 miles outward into the basin.

The relationship of the Aux Vases to the underlying Spar Mountain Sandstone Member of the Ste. Genevieve can best be seen in the cross section in figure 15, which is constructed perpendicular to the southeast-trending Central Valley (fig. 14). The cross section shows a 100-foot section of Aux Vases sandstone facies lying directly on the Fredonia Limestone Member of the Ste. Genevieve. Wells on either side of the sandstone body penetrate siltstone or shale of the Spar Mountain, whereas both the Spar Mountain and the overlying Karnak Limestone Member of the Ste. Genevieve are absent in the two wells that penetrate thicker sections of the Aux Vases Sandstone (fig. 15).

Interpretation

The absence of the Spar Mountain Sandstone Member of the Ste. Genevieve Limestone along most of the southwestern margin of Illinois was the result of erosion preceding deposition of the Aux Vases Sandstone. All three valley features probably were incised prior to, or in the early stages of, deposition of the Aux Vases. The incised valleys were filled subsequently by the Aux Vases Sandstone.

The incised valleys were almost certainly formed by fluvial erosion; however, the valley-fill sediments can reflect multiple depositional environments (Dalrymple et al. 1994). Two outcrop examples of the valley-fill strata can be seen at Stops 3 and 5. The erosional surface of the incised valleys marks a sequence boundary. The limestone pebble conglomerate on top of the sandstone at Hickman Creek, St. Clair County, Illinois (Stop 5), is interpreted to have been eroded from the Ste. Genevieve Limestone exposed in the interfluvial areas between incised valleys.

Economic Aspects

The Aux Vases is a major freshwater aquifer in southwestern Illinois. The aquifer occurs at a depth of about 300 feet (100 m) near the outcrop belt. Poor wells produce 5 to 25 gallons a minute, whereas better wells produce 50 to 75 gallons per minute (Ross D. Brower, Illinois State Geological Survey, personal communication, 1996). The probability of finding better-quality aquifers is increased by drilling into an Aux Vases incised valley. Outside the incised valleys, sandstones have poor permeability; in many places, the sandstones are replaced by siltstones.

Although not currently quarried in either Missouri or southwest Illinois, the Aux Vases was used to build the piers of the Eads Bridge in St. Louis and is still a potential source of construction material. In eastern Illinois, the Aux Vases produces significant amounts of oil, but none is produced near the southwest outcrop area.

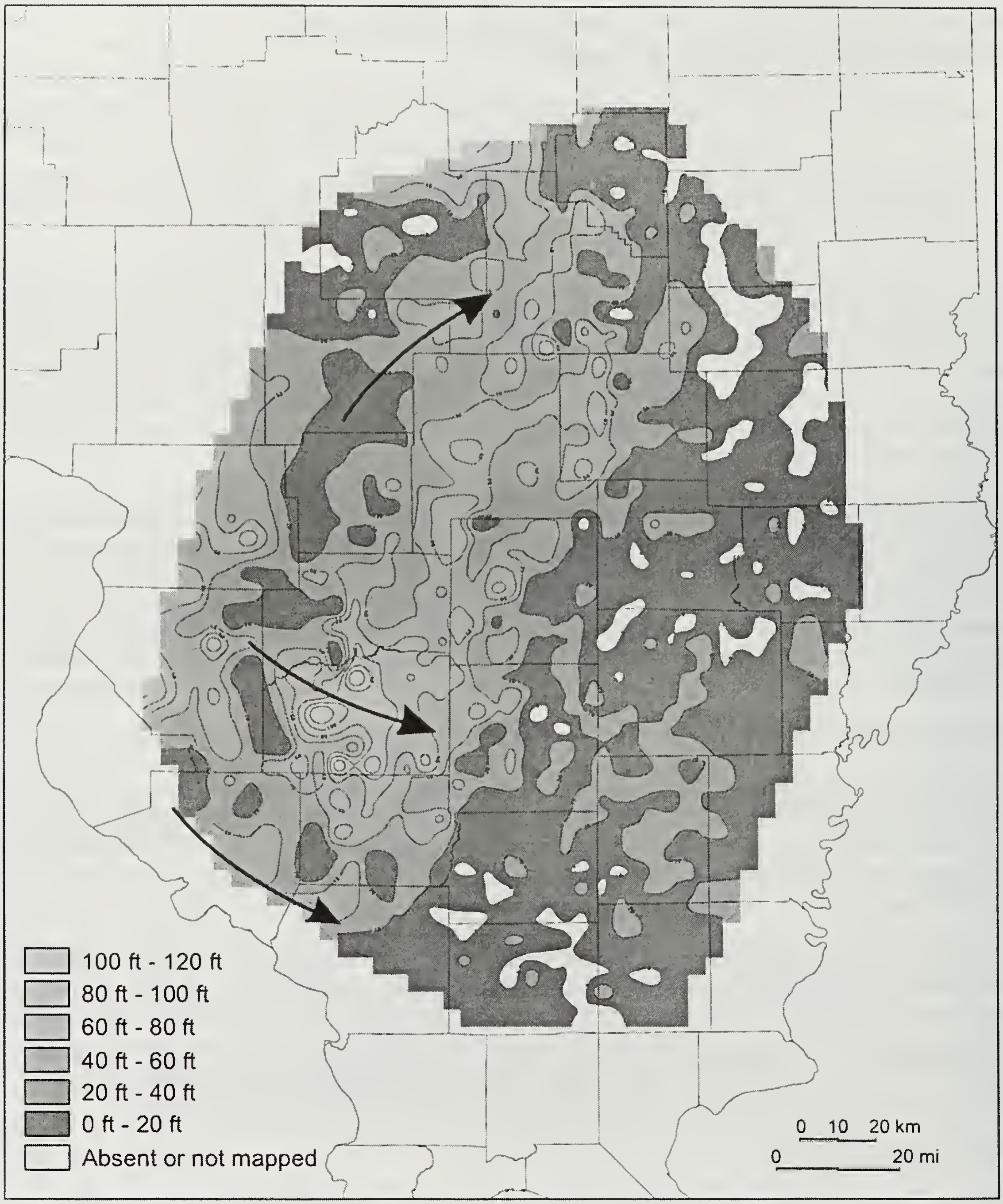

Figure 13 Sandstone isolith map for the Aux Vases Sandstone (modified from Leetaru 1997).

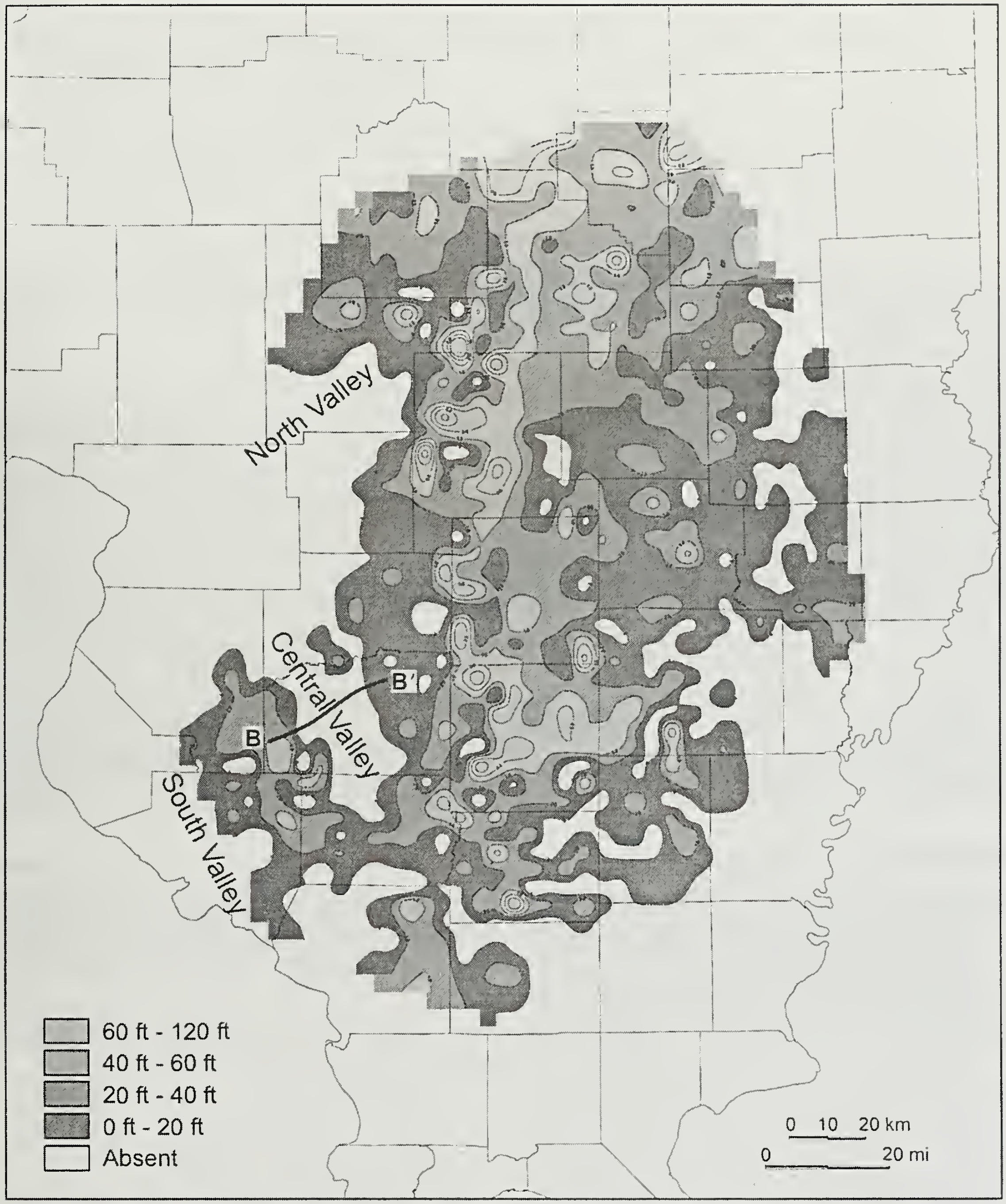

Figure 14 Isopach map of the Spar Mountain Member of Ste. Genevieve Limestone. North Valley, Central Valley, and South Valley features are areas where the Aux Vases has eroded into or through the Spar Mountain. Cross section B–B′ is shown in Fig. 15 (modified from Leetaru 1997).

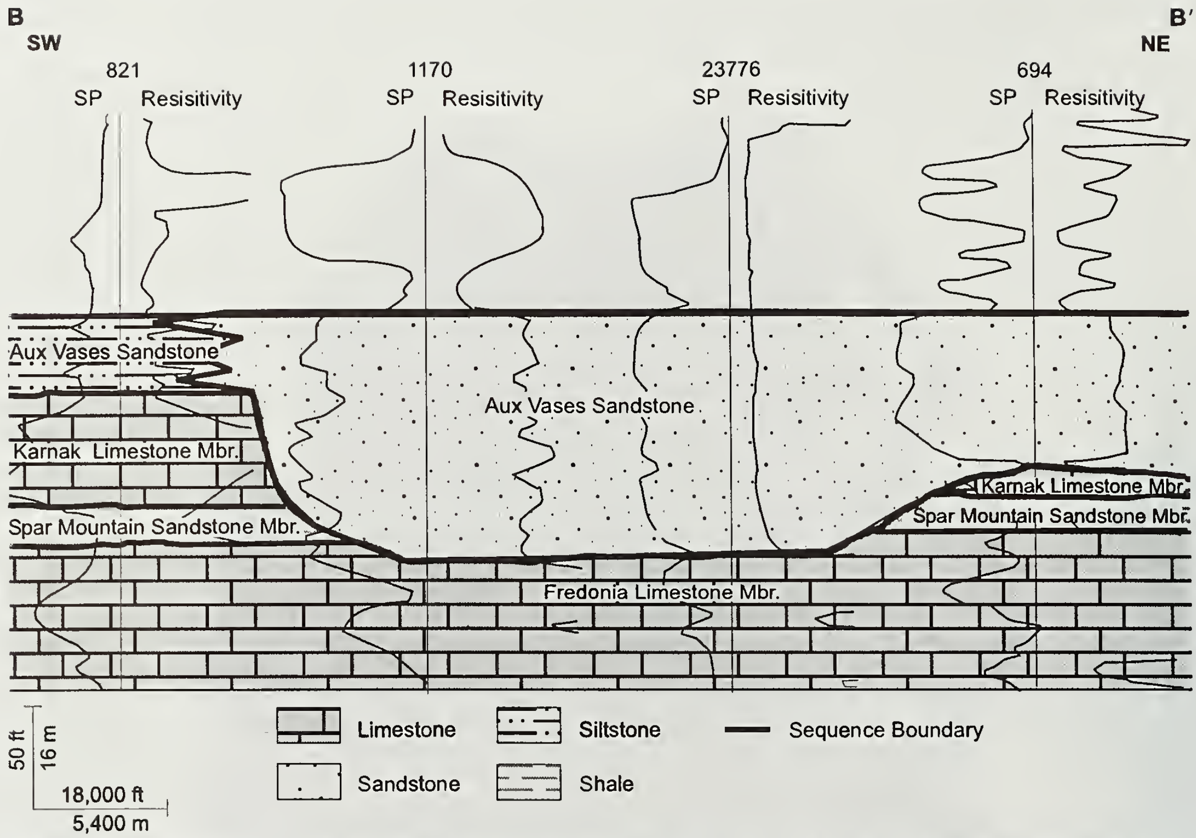

Figure 15 Cross section B–B′ perpendicular to central valley (Fig. 14). The Spar Mountain is a shale in this area (modified from Leetaru 1997). The well numbers are abbreviated API numbers.

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DIAGENESIS OF MISSISSIPPIAN LIMESTONES IN WESTERN ILLINOIS—*Bruce W. Fouke*

The upper Valmeyeran Series (Middle Mississippian) limestones exposed in western Illinois were deposited in an upward-shallowing, marine, carbonate-ramp setting on the west margin of the Illinois Basin (Cluff 1984, Lineback and Cluff 1985, Lasemi et al. 1998; see also pp. 1–18.) These rocks consist of deeper-water, fossiliferous grainstone/packstones and shale of the Warsaw Formation (fig. 16A, B) that are overlain by shallower water wackestones, packstones, and grainstones of the Salem, St. Louis, and Ste. Genevieve Limestones (fig. 16C–H). The sandwave deposition of well-sorted, oolitic grainstones of the Ste. Genevieve Limestone indicates that as water depths decreased, wave energy generally increased (fig. 16G, H).

Reconnaissance petrographic analysis of diagenetic alteration in these Mississippian limestones conducted in preparation for this field trip revealed that each of the formational units contains fundamentally different paragenetic sequences and associated diagenetic histories. These diagenetic fabrics and their distributions imply that (1) each of the lithologic units experienced significant diagenetic alteration prior to deposition of the overlying units and (2) burial diagenetic waters followed stratiform hydrologic conduits with relatively little cross-formational hydrologic flow.

Bryozoan-, echinoderm-, and brachiopod-rich Warsaw grainstone/packstones exposed at the Columbia roadcut (figs. 19, 20) and Beltrees (fig. 2) exhibit an early initial stage of leaching and recrystallization of aragonitic and high-magnesium calcite skeletal material (fig. 17A, B), whereas low-magnesium brachiopod shells remain relatively unaltered and have an extinct black cathodoluminescence (CL) (fig. 17C, D). This initial stage was followed by precipitation of 50- to 200-µm, bladed calcite crystal rims exhibiting concentrically zoned CL, which line intergranular pore spaces as well as leached biomolds. Precipitation of blocky calcite cement up to 300 µm in diameter with a bright, concentrically zoned CL was followed by precipitation of scattered, 150-µm replacement dolomite rhombohedra with an extinct black CL.

Medium-grained oolitic grainstones of the Salem Limestone that outcrop in the Prairie du Rocher area, Randolph County, Illinois, contain poorly developed rims up to 100 µm thick of dogtoothed calcite cement with a homogeneous CL (fig. 17E, F). Much of the remaining porosity is occluded by 50- to 100-µm-long blocky calcite crystals with concentrically zoned CL. A brecciated mudstone from the Salem–St. Louis boundary in Waterloo quarry (fig. 17G, H) contains an initial CL-zoned columnar calcite 150 µm in diameter, followed by precipitation of a large (up to 1 mm), concentrically CL-zoned, blocky calcite.

The skeletal mudstones and wackestones of the St. Louis Limestone exposed at Waterloo quarry (figs. 23, 24) and Casper Stolle Quarry (figs. 28, 29) contain coated grains and thinly laminated encrustations, within which skeletal material has been leached (fig. 18A, B). Partial rims of up to 200-µm-thick, dogtoothed calcite cements with a homogeneous CL occur between grains and in biomolds (fig. 18C, D). These cements are then encrusted by blocky calcite crystals 30 to 150 µm in diameter with concentrically zoned CL, which commonly coarsen toward the center of pores. A unique non-CL baroque dolomite (up to 4 mm in diameter) was observed in some samples; this is post-dated by a blocky calcite with concentrically zoned CL (fig. 18C, D).

The coarse-grained oolitic grainstones of the Ste. Genevieve Limestones exposed at White Hill quarry, SW Sec. 5, T14S, R2E, Johnson County, and Casper Stolle Quarry exhibit well-developed drusy rims of 50- to 150-µm, bladed calcite cements (fig. 18E, H). These cements exhibit concentrically-zoned to mottled CL and are overgrown by large (100 to 300 µm) blocky calcite crystals with concentric CL zonations.

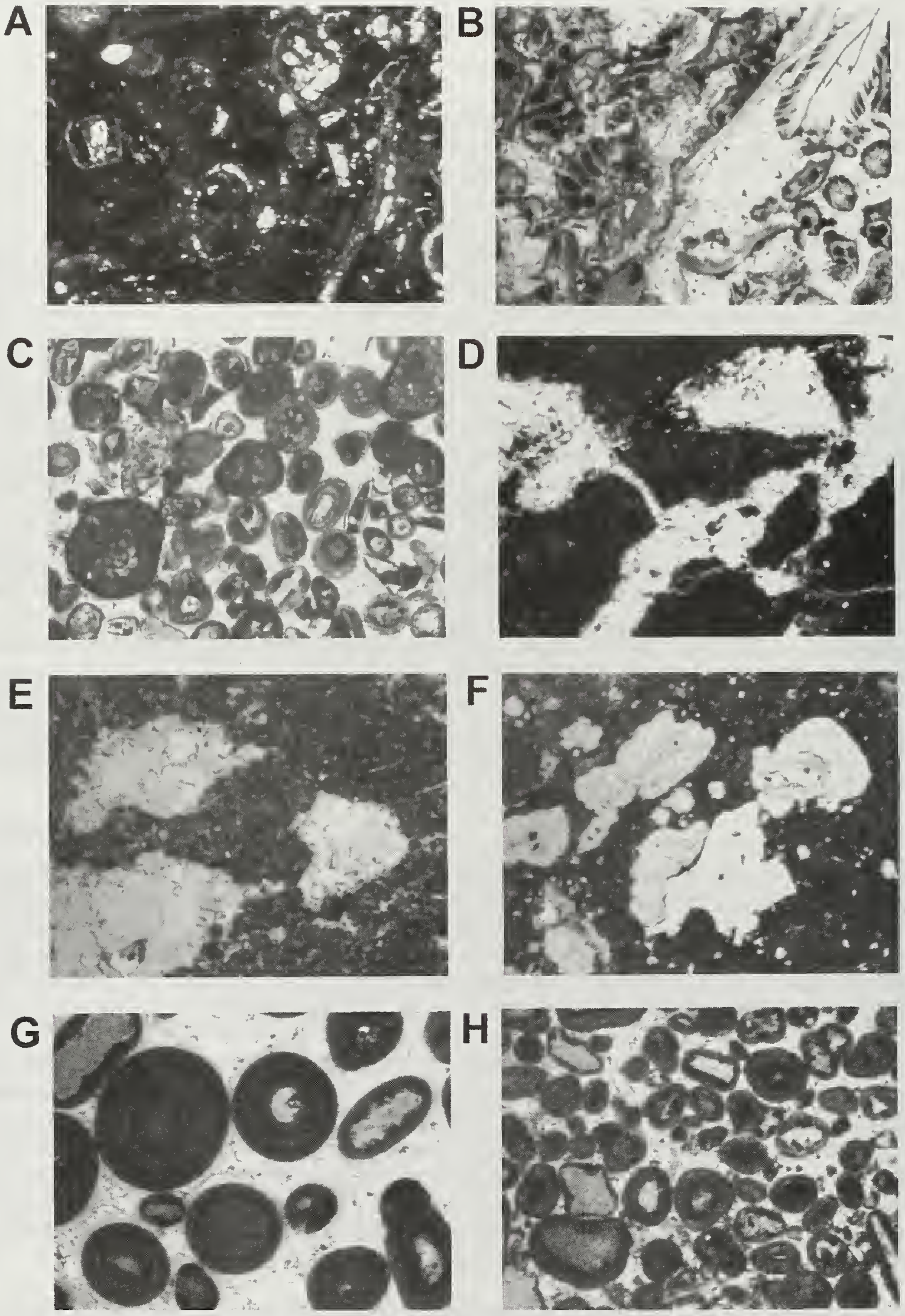

Figure 16 Plane-light photomicrographs of the primary depositional facies to be observed on this field trip (sample location abbreviations in parentheses and described in text); A, B, Warsaw Formation packstone and grainstone (BT and CRC); C, D, Salem Limestone grainstone (PDR) and lime mudstone (CWQ); E, F, St. Louis Limestone lime mudstone (CWQ) and wackestone (CSQ); G, H, Ste.Genevieve Limestone grainstone (WH and CSQ). Field of view photomicrographs is 2.5 mm across.

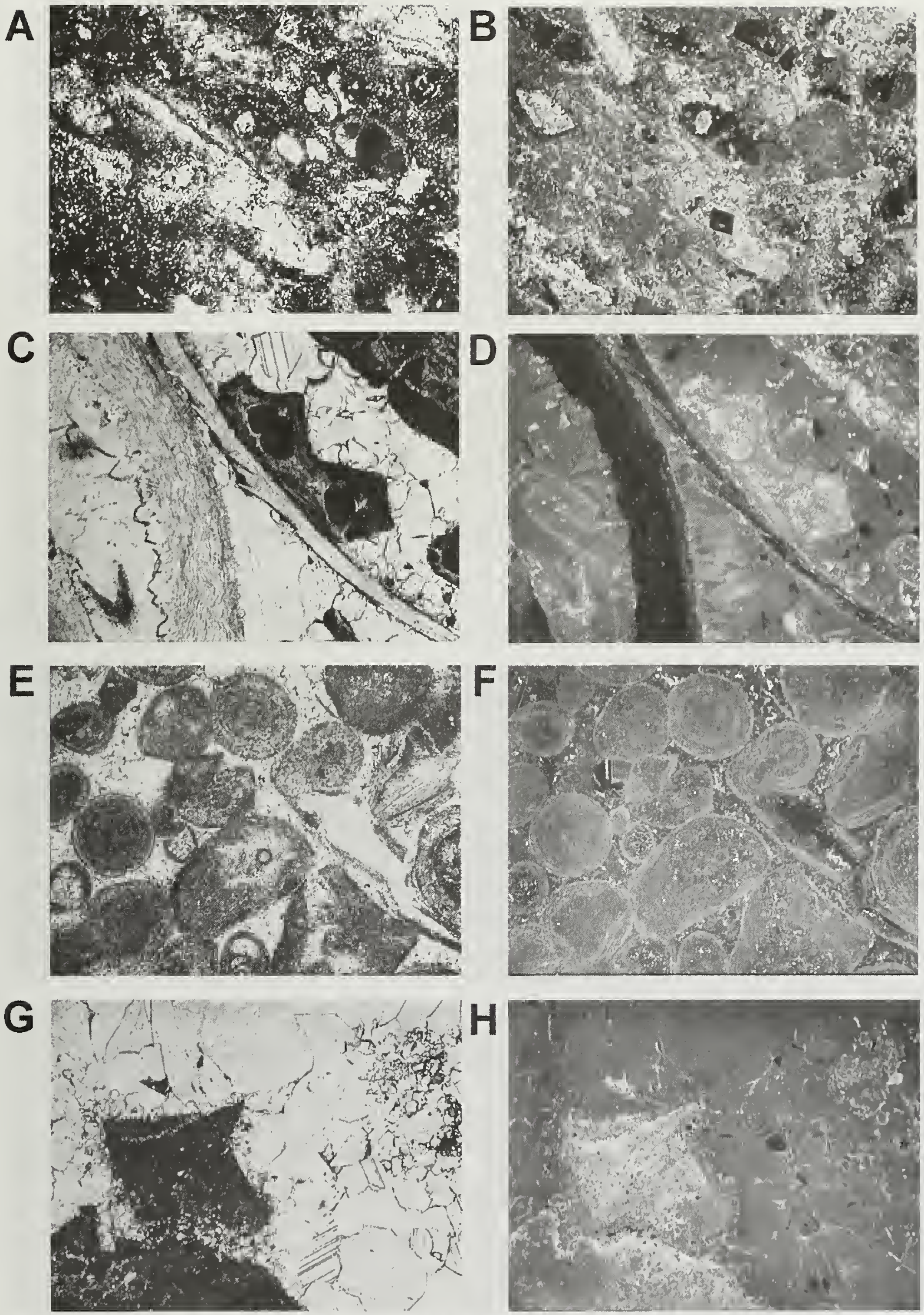

Figure 17 Paired plane-light and cathodoluminescence photomicrographs of the lithologies to to be observed on this field trip (sample location abbreviations in parentheses and described in the text); A, B and C, D, Warsaw Formation packstone and grainstone (BT and CRC); E, F and G, H, Salem Limestone grainstone (PDR) and lime mudstone (CWQ). Field of view in all photomicrographs is 2.5 mm across.

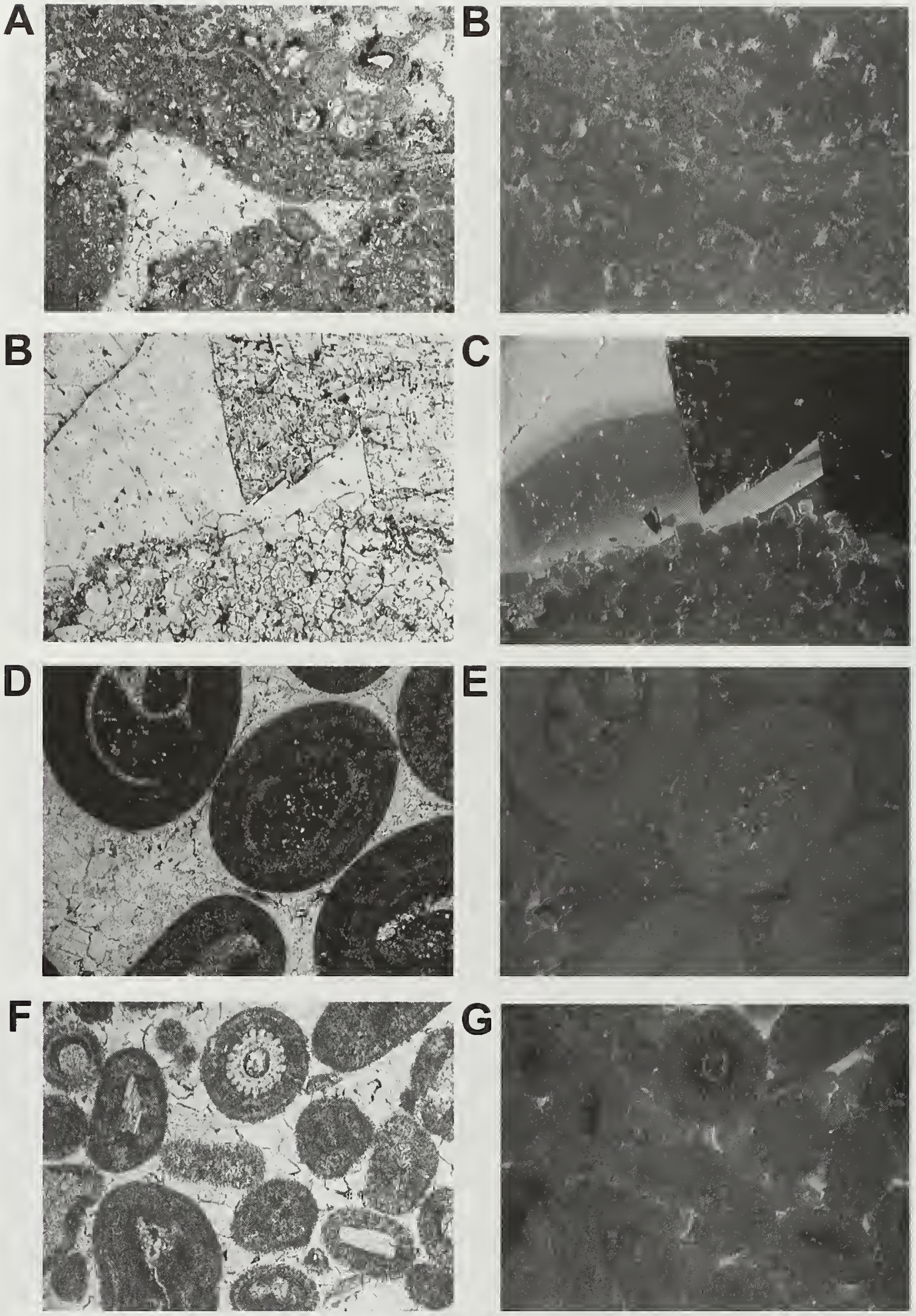

Figure 18 Paired plane-light and cathodoluminescence photomicrographs of the lithologies to be observed on this field trip (sample location abbreviations in parentheses and described in the text); A, B and C, D, St. Louis Limestone lime mudstones (CWQ) and wackestones (CSQ); E, F and G, H, Ste. Genevieve Limestone grainstones (WH and CSQ). Field of view in all photomicrographs is 2.5 mm across.

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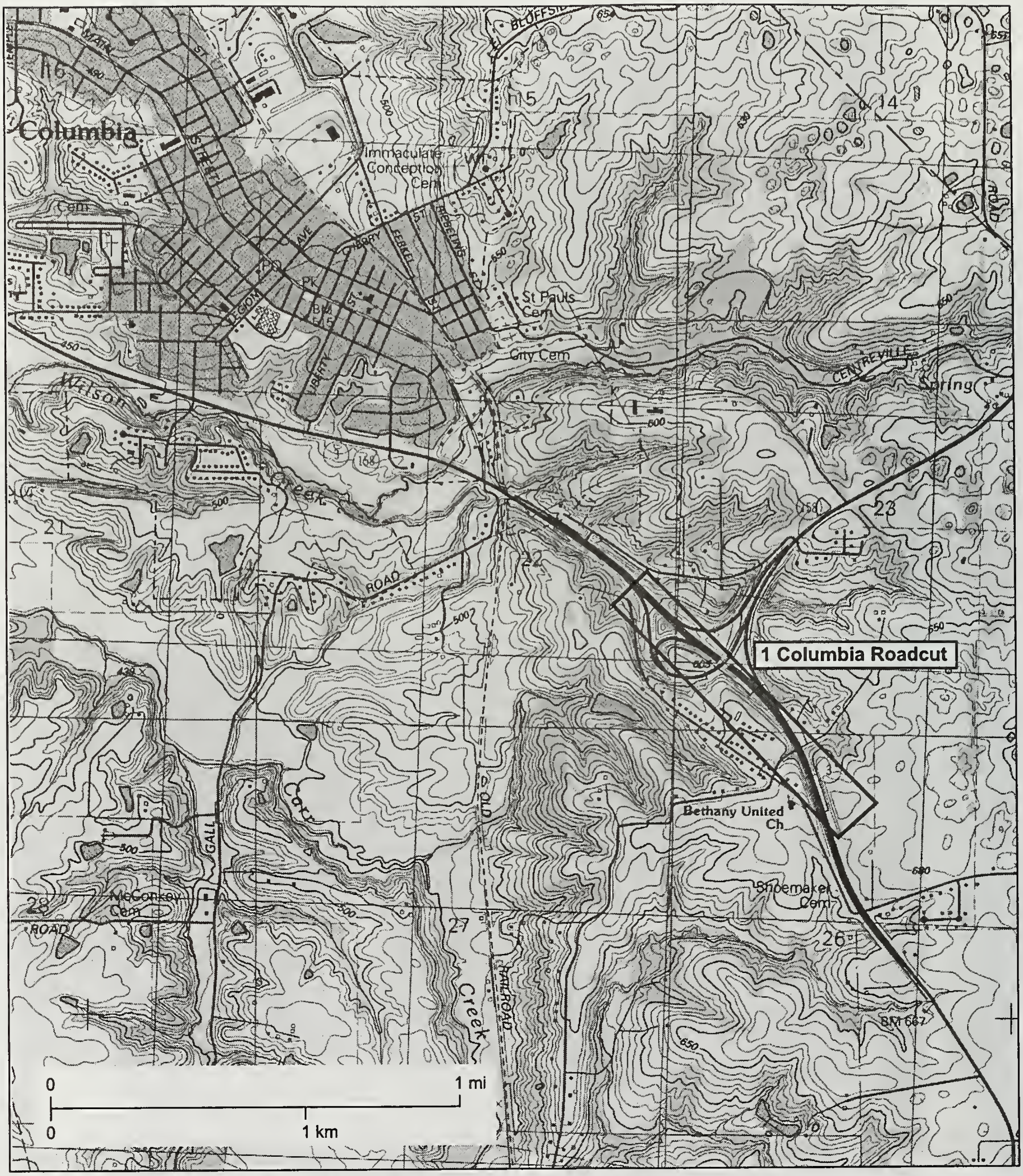


Figure 19 Location map of the Columbia roadcut (Stop 1) along IL Route 3, SE NE SE and NE SE SE Sec. 22, SW SW Sec. 23, and NE NW and SE NW Sec. 26, T1S, R10W, Columbia 7.5-minute quadrangle, Monroe County, Illinois.

STOP DESCRIPTIONS

Stop 1: Columbia Roadcut—*Zakaria Lasemi, Rodney D. Norby, and Bruce W. Fouke*

SE NE SE and NE SE SE Sec. 22, SW SW, Sec. 23, and NE NW and SE NW Sec. 26, T1S, R10W, Columbia 7.5-minute quadrangle, Monroe County, Illinois (fig. 19)

The Warsaw Formation and Salem Limestone (fig. 20a) are exposed near the crest of the Waterloo-Dupo Anticline (see pp. 19–22) in a long roadcut along IL Route 3 where it intersects IL Route 158 (fig. 21A). Stratigraphically higher beds (upper part of the Salem and lower beds in the St. Louis Limestone) are exposed nearby as tilted strata in a small creek on the south side of IL Route 3 (fig. 21B). Here, the St. Louis is mainly a lime mudstone with some stromatolitic laminations and fenestral fabric ("bird's-eye") typical of the lower St. Louis facies in the area. It is difficult to find the contact between the Salem and St. Louis in this creek. At this stop, we will examine depositional facies and discuss stratigraphic and sequence stratigraphic relationships between the lower Warsaw, upper Warsaw, and Salem.

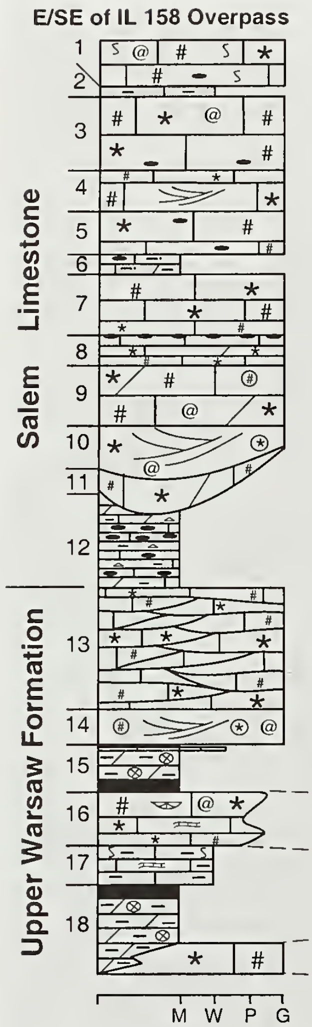
Warsaw Formation Baxter (in Keene 1969) first described the main section as consisting of 15 feet of Salem overlying 14 feet of Warsaw Shale. Additional strata are exposed above and below Baxter's main section. The entire section was redescribed by Collinson et al. (1979), and the name Ullin Limestone was substituted for the limestone portion (upper part) of the Warsaw Formation; a revised section was also given by Norby et al. (1989). It has frequently been suggested that the carbonates overlying the shale of the Warsaw represent the feather-edge of the area of Ullin deposition.

After careful lithologic and petrographic re-examination, we believe that most of what was previously referred to as Ullin should be assigned to the upper Warsaw. This assignment would support the argument of Kammer et al. (1990) that although the Ullin has general lithologic characteristics in common with the upper Warsaw, the upper Warsaw is the more appropriate term to use here. We recommend that the name Ullin be restricted to sections devoid of siliciclastics. We place the contact between the lower and upper Warsaw at a horizon where the shale-dominated interval grades into a carbonate-dominated (primarily a crinoidal-bryozoan grainstone) interval (figs. 20a and 21A). This horizon generally correlates with the disconformity surface we have found in the area (fig. 2) and the faunal break reported by Kammer et al. (1990).

Here, the lower Warsaw is dominantly a shale with some crinoidal limestone interbeds. The lower Warsaw is exposed in a slope below road level on the north side of IL Route 3 and at the base of cuts on both sides of Route 3. Beds of argillaceous, silty, finely crystalline dolomite with small geodes of pink dolomite are also present. Some beds contain abundant brachiopods and bryozoans.

The upper Warsaw is exposed mainly on the south side of Route 3 (fig. 21A) and is primarily a partly dolomitic, crinoidal-bryozoan grainstone in the lower 10 to 12 feet. This cross-laminated, crinoidal-bryozoan grainstone (fig. 3A), which is lithologically similar to the upper Ullin in southern Illinois, laterally grades into shales and argillaceous dolomites similar to those in the lower Warsaw. Above this grainstone, Warsaw carbonates become better sorted, and some beds contain coated grains (superficial ooids or pseudo-ooids), which suggests a shallowing of the environment toward the end of upper Warsaw deposition. In west-central Illinois (e.g., Adams County) and southeast Iowa, this shallowing event was accompanied by subaerial exposure and erosion (see p. 7).

Salem Limestone A thinly bedded, cherty, siliceous, spiculitic limestone unit occurs above the Warsaw in this roadcut (fig. 22). This unit may be equivalent to the "Fults" Member (Baxter 1960) of the Salem Limestone (fig. 20a, Unit 12). The unit is a laminated, dolomitic, argillaceous, silty lime mudstone (fig. 3C) with some bioclastic packstone/grainstone lenses. The interval is similar



Salem Limestone

Units 1- 9 (33.3 ft). Limestone, grainstone predominates, light brownish gray, weathers tan to light gray, fine to medium grained with some very fine and coarse grained, bioclastic, primarily echinoderm and bryozoan, rare forams and gastropods; unit 1, heavily burrowed (*Thalassinoides*-type) in upper part; unit 2, rusty weathering beds with some glauconite; unit 3, a line of concentrically banded spheroidal to elongate chert near the base; unit 4, cross-laminated; unit 5, finely laminated with occasional chert and escape burrows; unit 6, lime mudstone to wackestone, argillaceous and dolomitic with some chert; unit 8, nodular chert bed at top; unit 9, massive dolomite to dolomitic limestone, some coated grains (pseudo-ooids).

Units 10 and 11 (8.0 ft). Limestone, grainstone, medium gray fresh, weathers yellowish brown, very fine to medium grained, bioclastic as above and some pseudo-ooids (?), cross-bedded, probably a channel; unit 11 partially dolomitized, channelized into underlying unit.

Unit 12 (6.0 ft). Limestone, mostly lime mudstone with some dolomite, brown to grayish brown fresh, tan to light gray weathered, dolomitic in lowest and upper parts, siliceous, abundant sponge spicules, laminated, thin to very thin bedded; generally very cherty; cherts mottled white, to light to dark gray to orange and brown. Unit ranges up to 9.5 feet due to channeling.

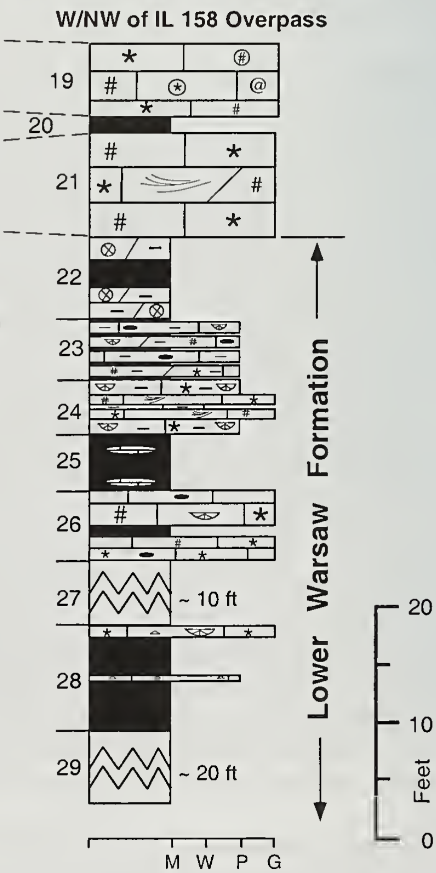
Upper Warsaw Formation

Unit 13 (10.5 ft). Limestone, light gray, thin, nodular bedded, medium-grained, moderately well-sorted, crinoidal-bryozoan grainstone; similar to Kidd Member (Baxter 1960).

Unit 14 (3 ft). Limestone, medium gray to brownish gray, medium to coarse, cross-bedded, crinoidal, bryozoan, and brachiopod grainstone, well rounded and moderately sorted with common coated grains and rare forams.

Units 15 (4 ft), **18** (4.5 ft), **& 20** (0.7 ft). Dolomite, argillaceous to very argillaceous, light to medium olive gray to blue gray with small geodes and shale, dark blue gray, dolomitic (?).

Unit 16 (4.6 ft). Limestone, medium gray with reddish brown tinge, medium to coarse, bioclastic packstone with dolomitic matrix; allochems include crinoids, bryozoans (some large, encrusting type?), brachiopods, and rare gastropods and bivalves. Some rip-up clasts and/or scour-filled lime mudstone. Unit appears to be laterally equivalent to unit 19.



Unit 17 (3.5 ft). Limestone, argillaceous, light olive gray, weathers very light gray, heavily burrowed at top, bioclastic (primarily crinoids, bryozoans, and brachiopods) wackestone and some packstone.

Unit 19 (6.5 ft). Limestone, gray to medium dark gray, medium grained, bioclastic (echinoderms, bryozoans, brachiopods, and rare forams and gastropods) grainstone, moderately sorted, common coated grains near base.

Unit 21 (9.5 ft). Limestone, light gray, medium to coarse grained, crinoidal-bryozoan grainstone, poorly sorted, common lime mudstone rip-up clasts, laminated to cross-laminated.

Lower Warsaw Formation

Units 22-29 (66.7 ft). Shale, limestone, and argillaceous dolomite; shale, dark olive brown, light blue gray weathered, in part dolomitic; grainstone and some packstone, light to dark gray, gray to brown weathered, some green tinge, fine to coarse grained, often poorly sorted, bioclastic (primarily bryozoans and echinoderms), in part argillaceous and slightly glauconitic, many large brachiopods in some beds; laminated to cross-laminated (hummocky) in some beds, small calcite and chalcedony nodules, some siliceous zones; dolomite, mainly in units 22 and 23, light olive gray, weathers tan, microcrystalline, silty, argillaceous; some pink dolomite and calcite geodes, locally fossiliferous, some silicified *Thalassinoides*-type burrows; a few very thin to nodular discontinuous chert and soft siliceous beds; approximately 30 feet covered (presumably shale) in lower part.

Figure 20a Stratigraphic column for the Columbia roadcut.See figure 20b for key.

to the argillaceous, dolomitic, cherty unit that regionally overlies the Ullin in the subsurface (Lasemi et al. 1998) and appears to be equivalent to the Somerset Shale (Benson 1976) that widely occurs at a similar horizon in Indiana and Kentucky.

Abundant sponge spicules and *Zoophycos* burrows (seen in nearby cores) along with the absence of any shallow water facies suggests that this cherty unit was deposited in a relatively deep water setting. Because of the widespread presence of this unit throughout the Illinois Basin and adjacent regions, we place the Ullin/upper Warsaw–Salem contact at the base of this cherty unit. We interpret this unit to represent a deepening event following deposition of the shallow water facies of the uppermost part of the Ullin/Warsaw (Lasemi et al. 1998).

The rest of the Salem in this section consists of a bioclastic-peloidal grainstone. The grainstone facies of the Salem in this section was deposited as cyclic carbonate sand shoals and tidal channels. The cycles can best be seen in the quarry exposure at Stop 2. The grainstone facies consists of fine- to medium-grained, rounded and moderately sorted crinoidal-bryozoan fragments. Forams, some peloids, and rare coated grains (pseudo-ooids) are also present. Petrographically, the Salem here appears to be similar to the uppermost part of the upper Warsaw, which indicates deposition generally in a similar environment.

Tilted beds (angles of 15° to 25° dip), representing parts of the upper Salem and lower St. Louis (fig. 21B) occur in a creek bed that runs below the south side of IL Route 3. Some beds may be repeated due to faulting in this section. These tilted beds in the creek section are part of the more steeply dipping western limb of the Waterloo-Dupo Anticline (Nelson 1995).

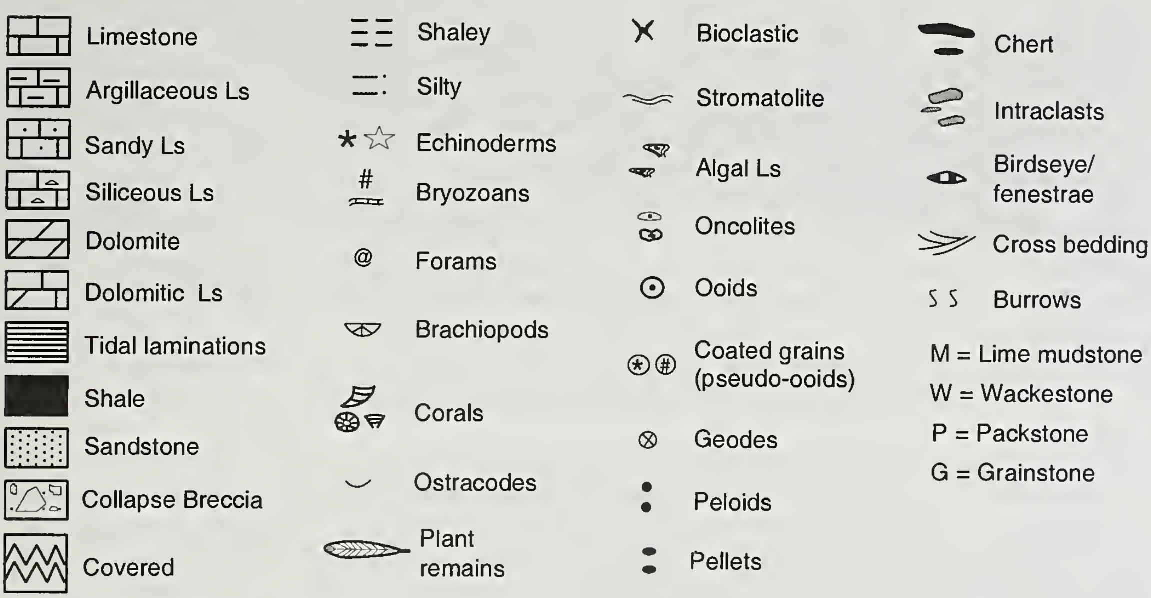


Figure 20b Key to figures 20a, 25, 29, 35, and 38a.

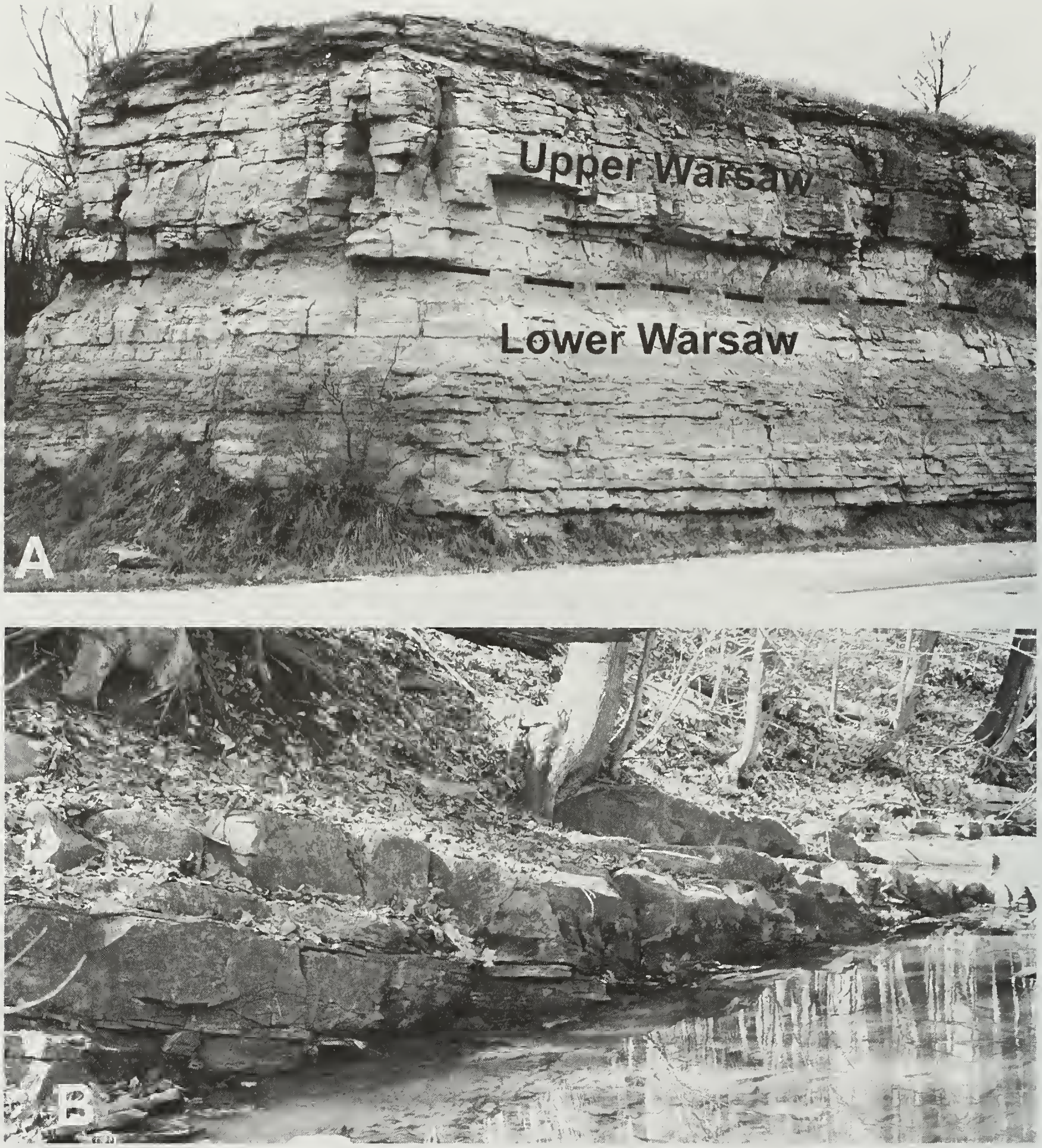


Figure 21 (A) The Columbia roadcut showing part of the lower and upper Warsaw Formation (separated by dashed line). (B) Creek section along IL Highway 3 showing tilted strata of the St. Louis Formation.

Figure 22 The Columbia roadcut showing the "Fults" Member of the Salem overlain by a bioclastic, slightly oolitic grainstone facies of the Salem.

Stop 2: Waterloo Quarry—*Zakaria Lasemi and Rodney D. Norby*

NW and NE Sec. 8, T3S, R9W, Paderborn 7.5-minute quadrangle, Monroe County, Illinois (fig. 23)

In this quarry, we will examine the upper part of the Salem, the lower St. Louis, and the upper St. Louis (fig. 24). A prominent unconformity marks the Salem–St. Louis boundary in this section (fig. 10). The "Lost River Chert" zone (Norby and Lasemi 1999), a widespread stratigraphic marker in the Illinois Basin, also occurs in the upper part of the St. Louis at this stop (see pp. 14–15). The top of the St. Louis in this quarry may be an unconformity. It consists of a fossiliferous chert pebble conglomerate, possibly derived from cherts in the "Lost River Chert" zone. Lithologically, the lower St. Louis here contains a more normal marine facies in the upper part and a restricted marine facies in the lower part. The lower St. Louis grades southward into the oolitic, foraminiferal limestone of the upper Salem in the Renault–Prairie du Rocher–Ste. Genevieve area (see inside back cover).

Salem Limestone At least three shoaling-upward cycles of the Salem (fig. 24) are exposed in this quarry; each cycle consists of a bioclastic grainstone facies overlain by a thinner dolomitic, argillaceous, partly cherty intertidal facies, which, in places, contains thin, evenly laminated tidalite beds. Locally, the base of each cycle is an intraclastic limestone. With respect to aggregate quality, the grainstone facies of each cycle is a pure, dense, high-calcium limestone, whereas the intertidal facies is a soft, poor quality, argillaceous and partly dolomitic limestone.

Here, the Salem–St. Louis boundary is marked by a prominent unconformity, consisting of a karstic surface characterized by solution fissures and a brecciated and conglomeratic horizon (fig. 10). Laterally, this surface becomes erosional and undulatory (figs. 25 and 26). A prominent shale bed, containing plant remains, overlies this surface (fig. 26). We have traced this unconformity from the Alton area in the north to Ste. Genevieve County, Missouri, to the south. In the Renault–Prairie du Rocher–Ste. Genevieve area, however, the unconformity occurs within the Salem, suggesting that the upper Salem here is equivalent to the lower St. Louis in the St. Louis metro area.

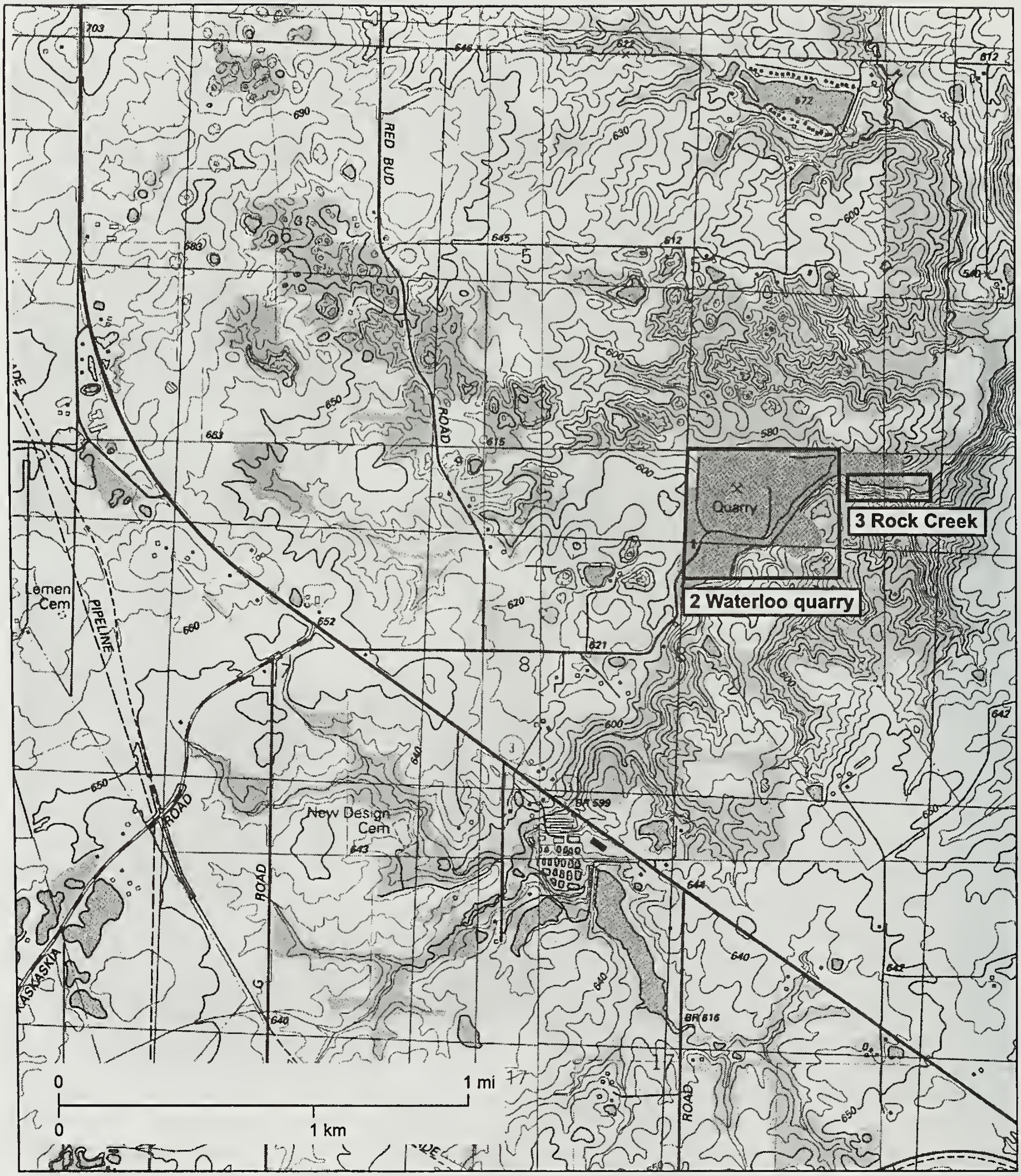


Figure 23 Location map of Columbia Quarry Company's Plant No.7 (Waterloo quarry, Stop 2), NW and NE Sec. 8, T3S, R9W; Paderborn and Columbia 7.5-minute quadrangles, Monroe County, Illinois, and the Aux Vases Sandstone on Rock Creek (Stop 3), NE NE NE Sec. 8 and NW NW NW Sec. 9, T3S, R9W.

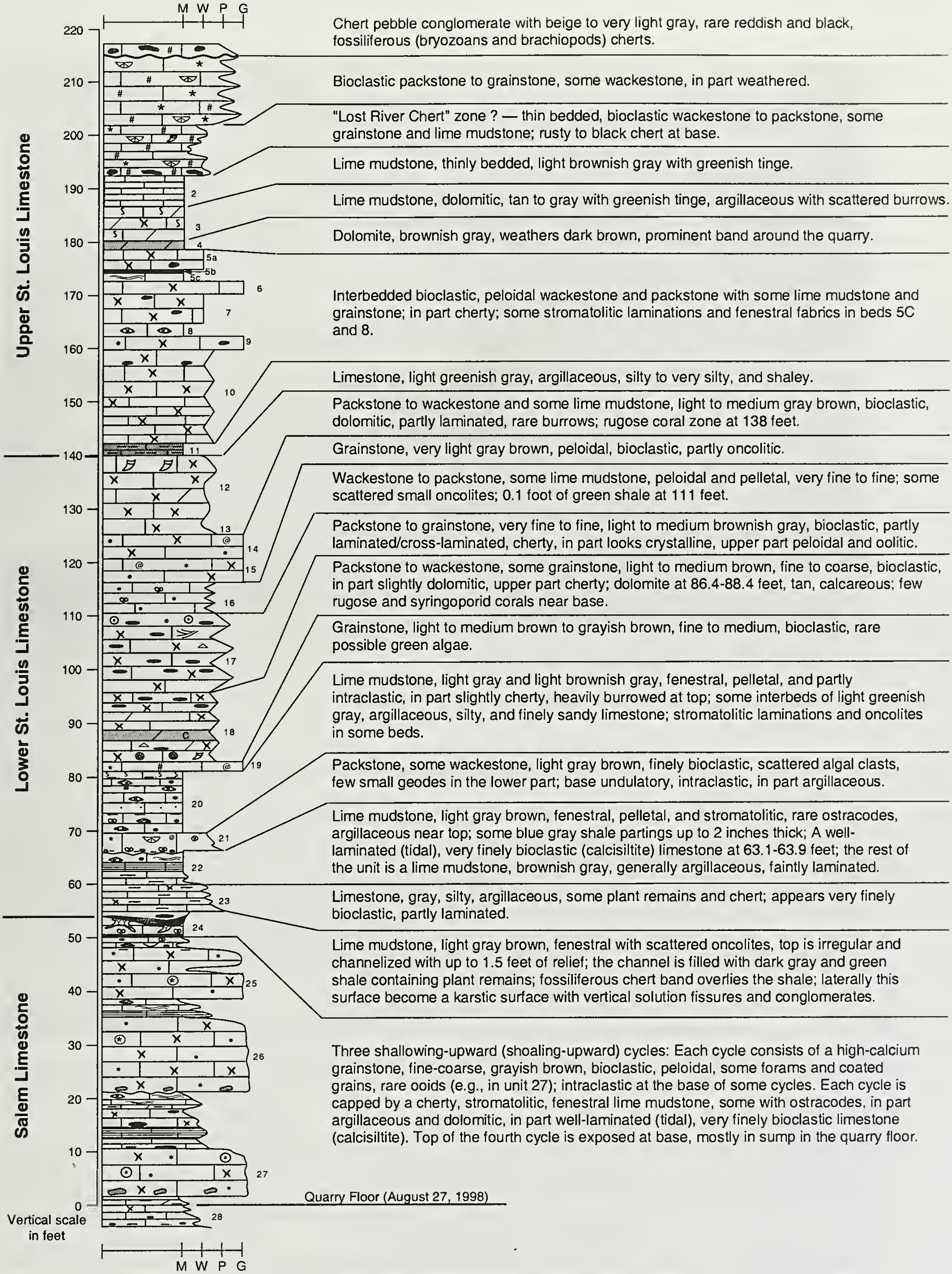
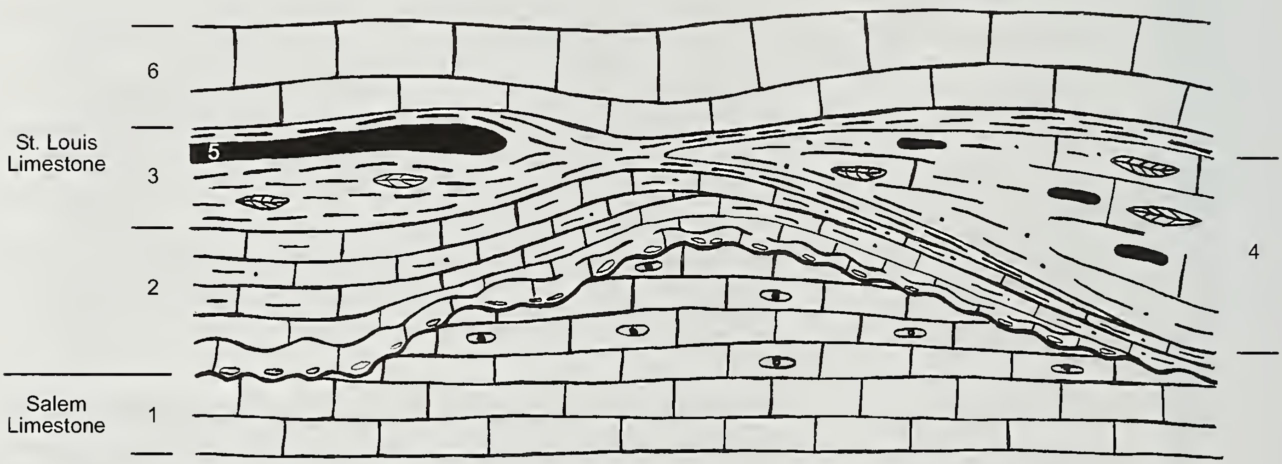


Figure 24 Stratigraphic column of the Waterloo quarry. See figure 20b for key.

Figure 25 Channelized surface of the Salem–St. Louis boundary (white dashed line), Waterloo quarry (see fig. 26 for details). Hammer for scale.



ST. LOUIS LIMESTONE

6. *Limestone*, grayish brown, very fine grained.
5. *Chert*, light gray to dark gray with orange staining, pyritic, some fossils.
4. *Limestone*, upper channel-fill (?) bed contains some plant debris, much of which is asphaltic.
3. *Shale*, a dark greenish gray to black shale with plant debris, occurs adjacent to the upper channel-fill limestone and under- and overlies the limestone.
2. *Limestone*, light brownish gray, very fine grained, argillaceous, silty, very rubbly in lower few inches, a few clasts of the underlying bed present.

SALEM LIMESTONE

1. *Limestone*, brownish gray to grayish brown, very fine grained, small algal clasts throughout, fenestrae structures especially in the upper part, thickness varies from 3.0 to 3.7 feet; top very undulatory with range up to 1.5 feet; maybe a channelized surface.

Figure 26 Contact between the Salem and the St. Louis Limestones along the north ramp at the Waterloo quarry (see fig. 25). See figure 20b for key.

St. Louis Limestone Both the lower and upper St. Louis are exposed in this quarry (fig. 24). The lower St. Louis consists of a restricted marine limestone facies in the lower one third and a more open marine limestone facies in the upper two thirds. The restricted marine facies is characterized by stromatolitic lamination, fenestral fabric, pelletal limestone, and some microcrystalline dolomite and dolomitic limestone. Some bioclastic packstone and grainstone and oncolitic floatstone and rudstone are also present and may represent a tidal channel deposit. The open marine facies is primarily a bioclastic, partly cherty wackestone to packstone with some interbedded peloidal-bioclastic grainstone. From here southward, the whole lower St. Louis facies becomes an open marine facies that grades into the oolitic-peloidal-foraminiferal grainstone of the upper Salem (fig. 4B) in the Renault–Prairie du Rocher–Ste. Genevieve area.

The upper St. Louis is characterized by an open marine facies that consists of bioclastic wackestone, lime mudstone, and some peloidal-bioclastic grainstone. The "Lost River Chert" zone, consisting of thinly bedded, bryozoan-rich lime mudstone and wackestone, occurs in the upper part of the upper St. Louis. The interval above the "Lost River Chert" zone is primarily a packstone to grainstone. This interval is not present at all locations in the area, possibly because of truncation at the St. Louis–Ste. Genevieve boundary. A very cherty interval at the top of the St. Louis section here may represent a basal chert conglomerate that marks the St. Louis–Ste. Genevieve unconformity. The source of the chert, which contains abundant bryozoans, may be the "Lost River Chert" zone.

The boundary between the lower and upper St. Louis is not easily recognized here. The collapsed breccia bed, which marks the top of the lower St. Louis in other areas to the north, is not present in this quarry. We have identified an argillaceous, greenish gray lime mudstone at or just above the boundary (fig. 24). This argillaceous unit correlates with a similar unit above the main breccia at the upper–lower St. Louis boundary in the Alton area. This unit can be traced from the Alton area (Stop 6 and 7) in the north to the Prairie du Rocher–Ste. Genevieve area to the south. In some areas, this horizon is shaley, and in the Ste. Genevieve area, it becomes a shale with common fish teeth.

Stop 3: Rock Creek—*Hannes E. Leetaru*

NE NE NE Sec. 8 and NW NW NW Sec. 9, T3S, R9W, Paderborn 7.5-minute quadrangle, Monroe County, Illinois (fig. 23)

There is no Aux Vases Sandstone at the top of the Waterloo quarry; yet 0.6 mile to the northeast along Rock Creek, massive 80-foot bluffs of Aux Vases occur along the stream (fig. 27). The base of this thick, cross-bedded sandstone occurs 80 feet below the top of Waterloo quarry. Here, the Aux Vases consists of fine- to medium-grained quartz arenite that has abundant trough and tabular cross bedding.

Stop 4: Casper Stolle Quarry—*Zakaria Lasemi and Rodney D. Norby*

Approximately the NW of Sec. 13 and the NE of Sec. 14 extended, T1N, R10W; Cahokia 7.5-minute quadrangle, St. Clair County, Illinois (fig. 28)

The upper part of the Salem Limestone, the St. Louis Limestone, and most of the Ste. Genevieve Limestone are exposed in this 200-foot-deep quarry (fig. 29). We will examine the Salem–St. Louis boundary, lower and upper St. Louis facies, the "Lost River Chert" zone in the upper St. Louis, and the oolitic grainstone channel or shoal facies in the Ste. Genevieve Limestone.

Salem Limestone Only the uppermost 25 feet of the Salem is exposed here (fig. 29). The full Salem in this area is about 80 to 100 feet thick and consists of shoaling-upward cycles similar to, but thinner than, those seen at the Waterloo quarry. The Salem–St. Louis contact is marked by a

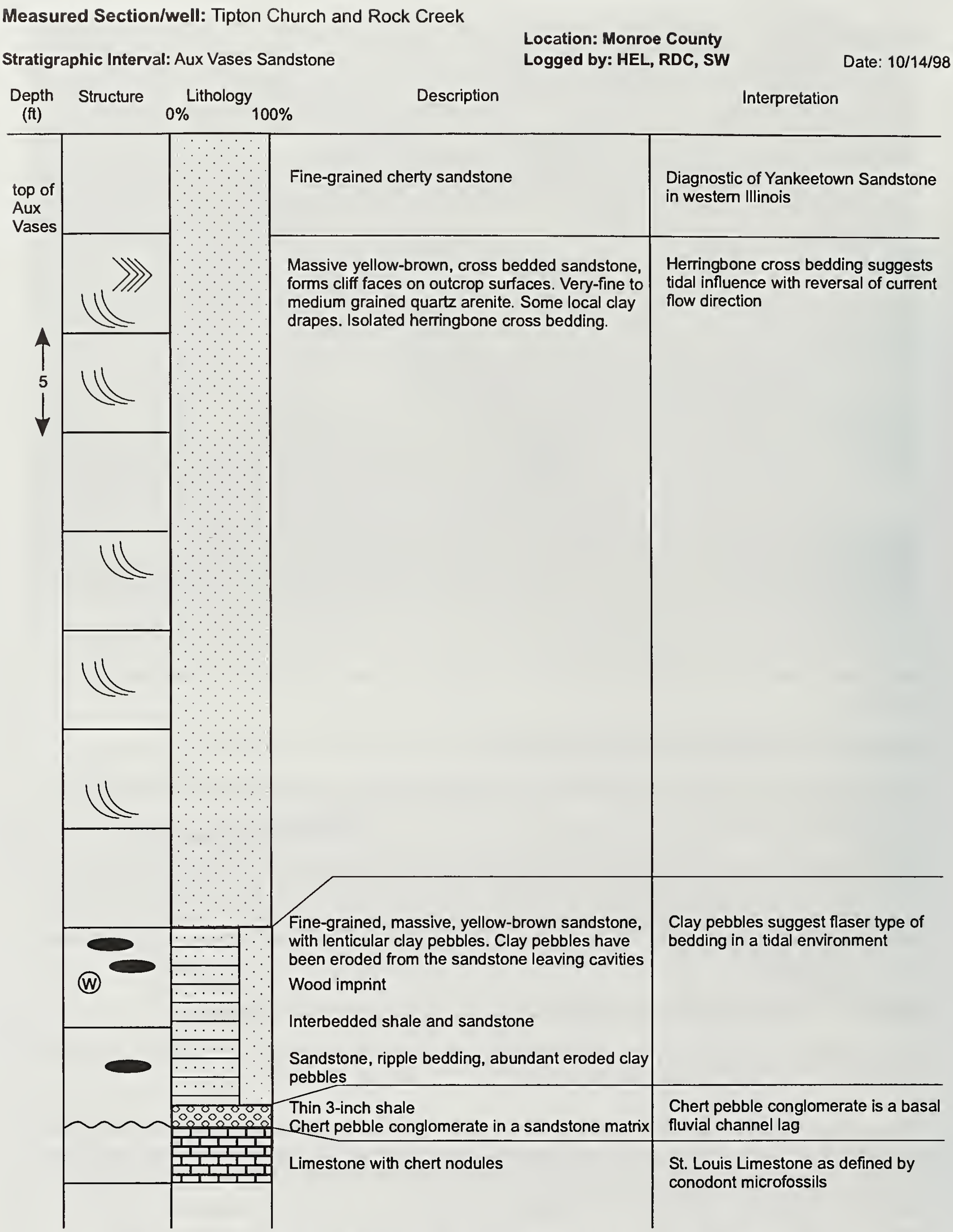


Figure 27 Measured section of the Rock Creek outcrop in Monroe County, Illinois (modified from Leetaru 1997). See figure 33 for key.

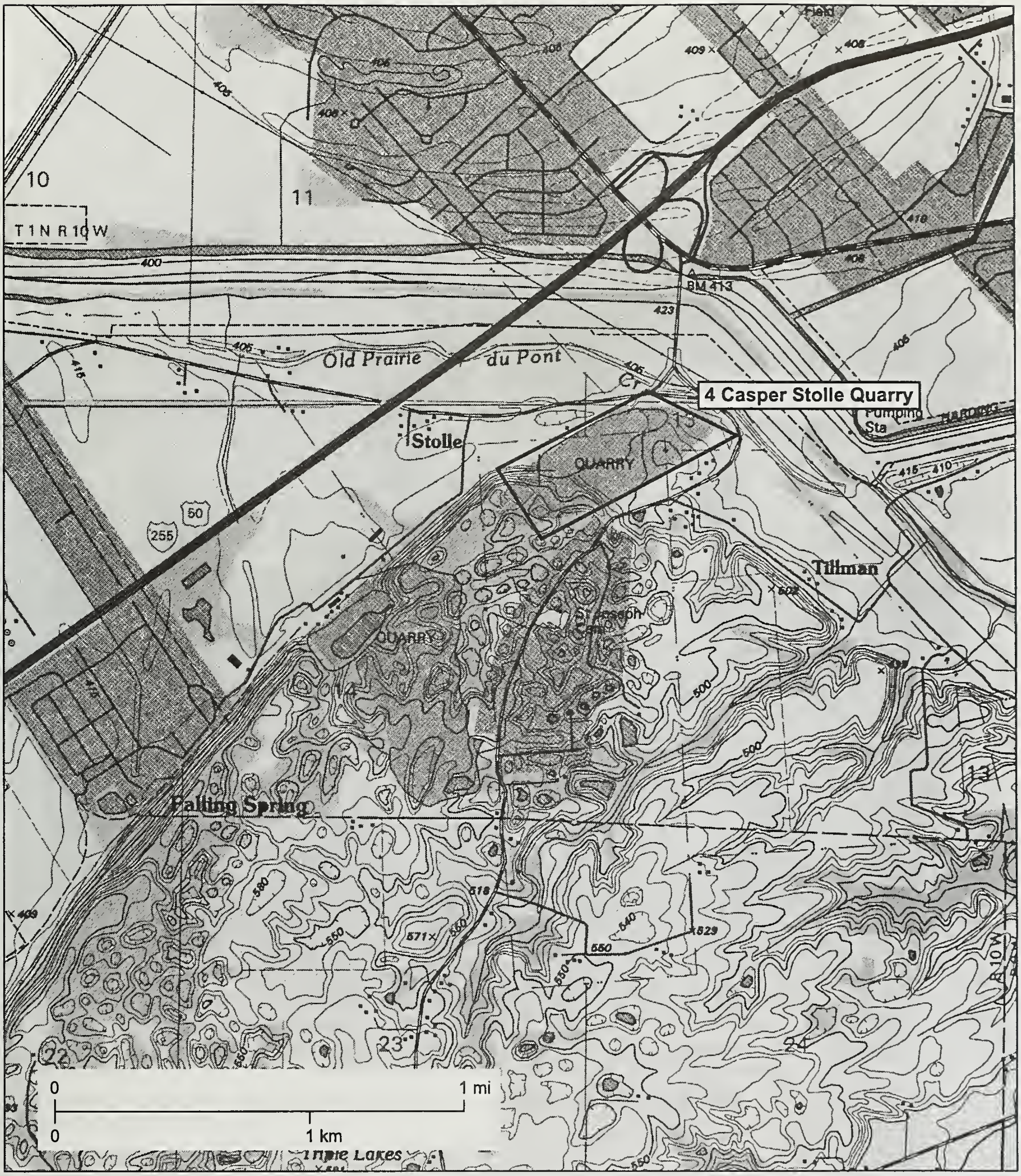


Figure 28 Location map of Casper Stolle Quarry (Stop 4), approximately the NW of Sec. 13 and the NE of Sec. 14 extended, T1N, R10W; Cahokia 7.5-minute quadrangle, St. Clair County, Illinois.

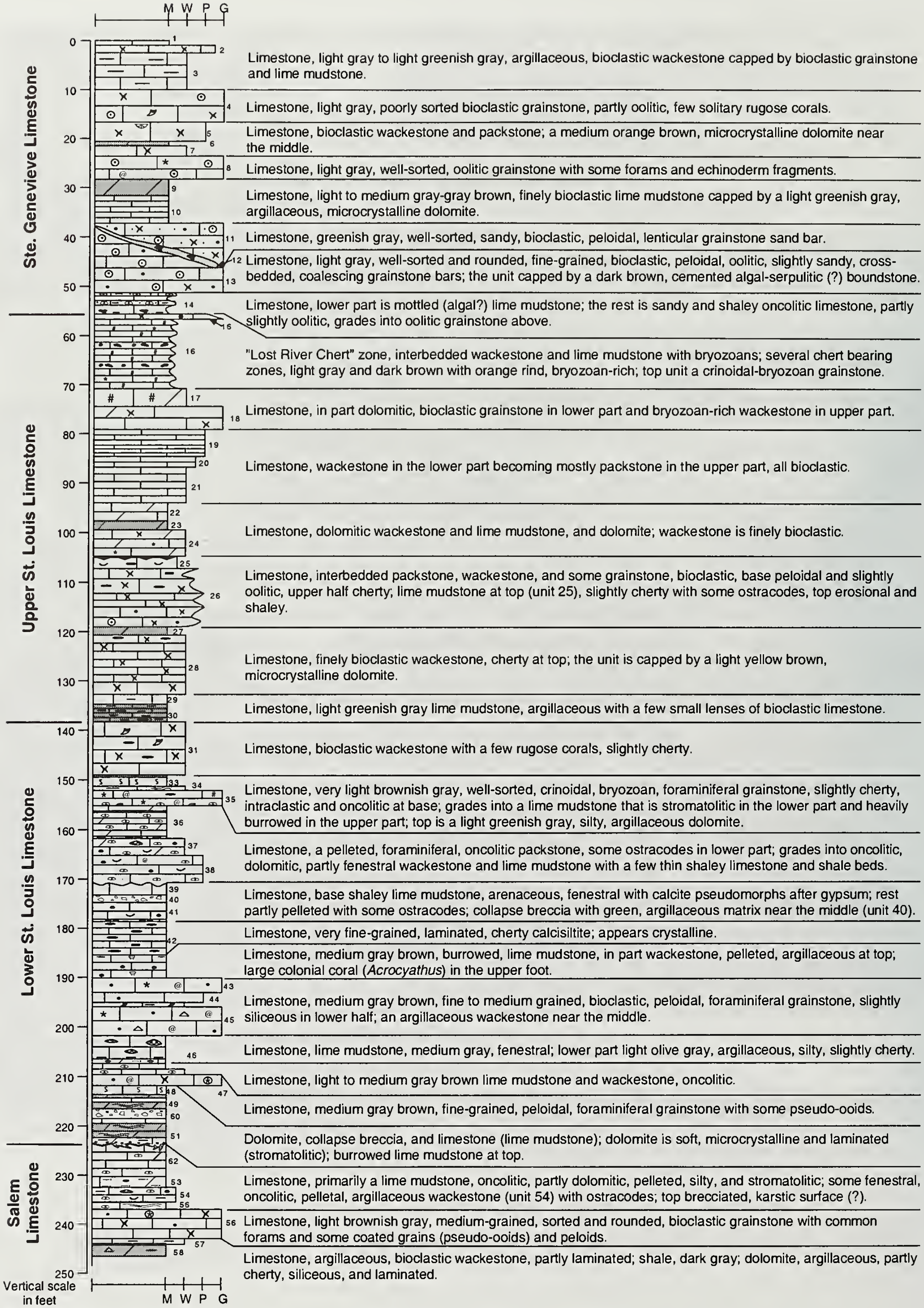


Figure 29 Stratigraphic column of Casper Stolle Quarry. See figure 20b for key.

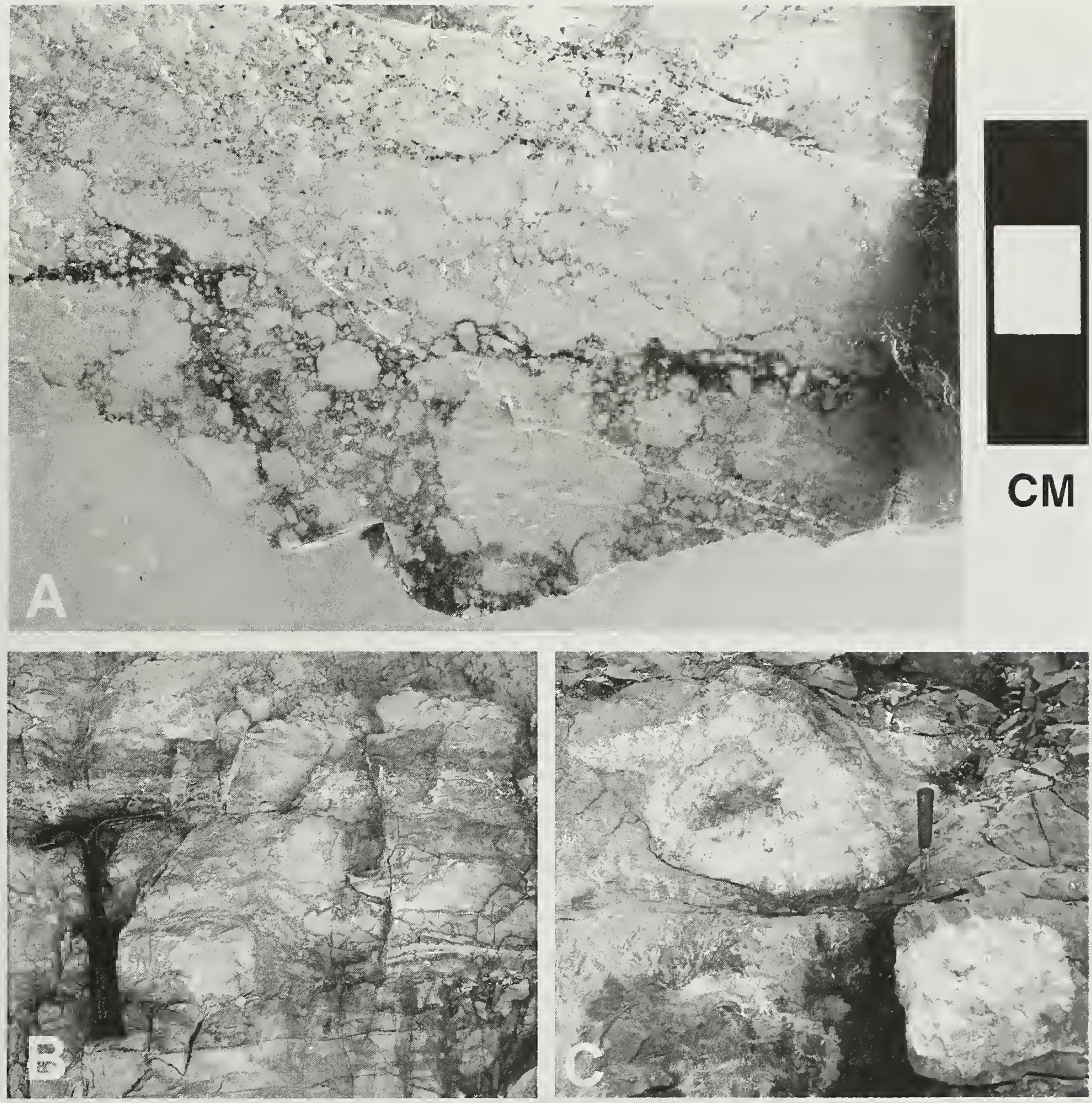


Figure 30 Features in the St. Louis Limestone at Casper Stolle Quarry. (A) The Salem–St. Louis contact shows a brecciated surface similar to that in the Waterloo quarry (fig. 10). (B) Collapsed breccia in the lower part of the lower St. Louis Limestone; hammer head is about 5.3 feet above the Salem–St. Louis contact. (C) Colonial coral *Acrocyathus* (= "*Lithostrotionella*") in the upper part of the lower St. Louis; hammer for scale.

thin karstic surface (fig. 30A) that is conglomeratic and/or microbrecciated and similar to that seen in the Waterloo quarry.

St. Louis Limestone Both the upper and lower St. Louis are exposed here (fig. 29). The lower St. Louis is dominantly a lime mudstone with some wackestone. Fenestral fabric, stromatolitic lamination, mudcracks, oncolites, and pelletal limestone are quite common, and several microcrystalline dolomite beds occur throughout. Two collapsed breccia beds also occur within the lower St. Louis in this quarry (fig. 30B). These breccia beds commonly occur in this interval at the margins of the basin and have been interpreted to be the result of dissolution of underlying or interbedded gypsum and anhydrite (Collinson et al. 1954, Collinson and Swann 1958). The colonial coral *Acrocyathus* (= "*Lithostrotionella*") occurs in the lower part of the lower St. Louis in this quarry (fig. 30C). That similar corals occur at the same horizon in age-equivalent strata of the Salem in

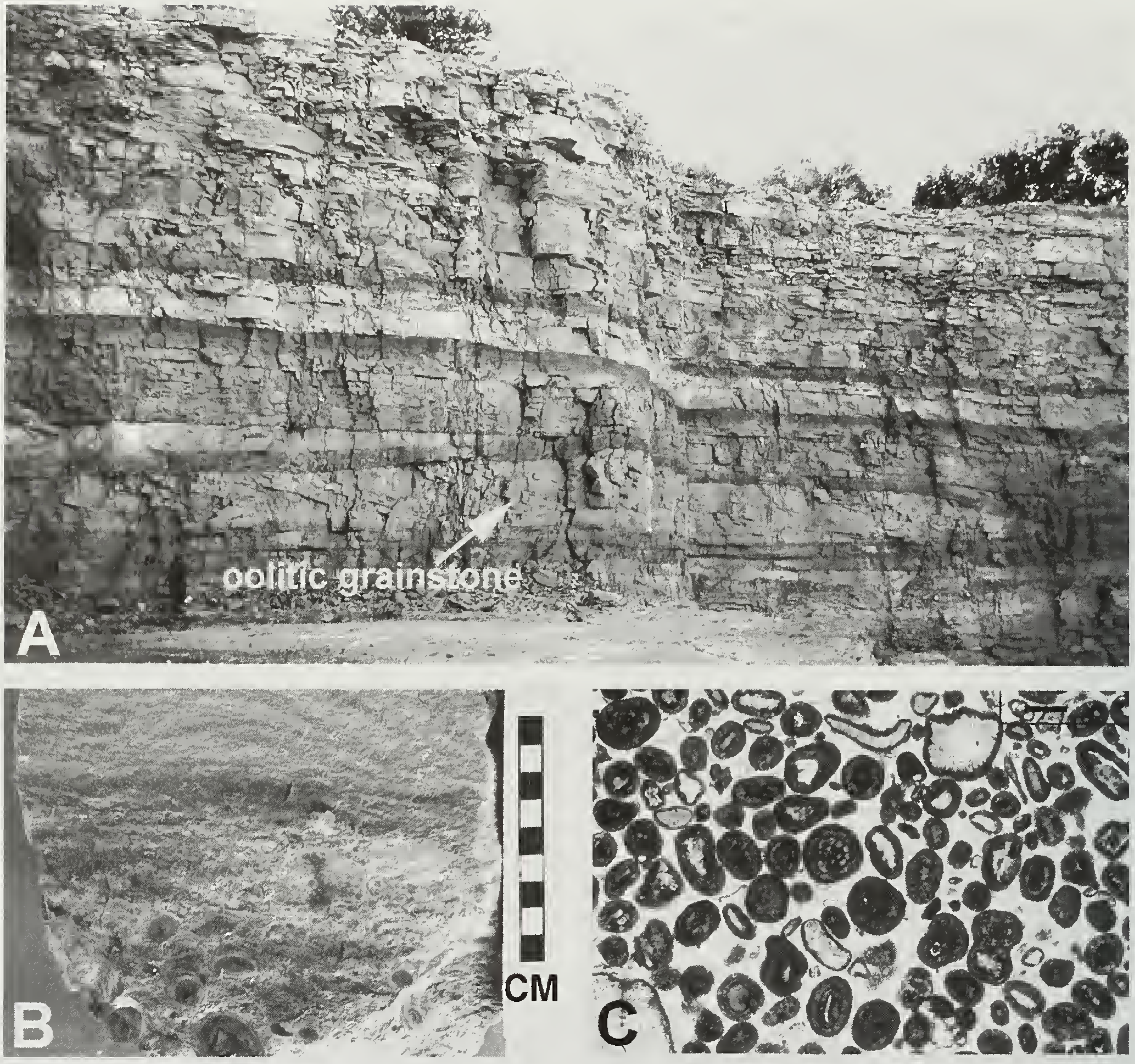


Figure 31 Features in the Ste. Genevieve Limestone at Casper Stolle Quarry. (A) Oolitic grainstone sandwave at the top of the quarry. (B) Oncolitic lag overlain by an oolitic grainstone near the base of the Ste. Genevieve. (C) Thin section photomicrograph of the oolitic grainstone; bar scale = 0.5 mm.

the Prairie du Rocher area supports the theory of lateral gradation between the lower St. Louis and upper Salem. Here, the lower St. Louis facies represents deposition in restricted lagoonal to intertidal–supratidal environments. Several oncolitic, peloidal, bioclastic packstone/grainstone beds (some intraclastic at base) are also present within the lower St. Louis in this section; they probably represent tidal channel deposits.

The upper St. Louis is dominantly a normal marine facies that consists primarily of bioclastic-peloidal wackestone and packstone interbedded with lime mudstone and some grainstone. The “Lost River Chert” zone occurs at the top of the upper St. Louis (fig. 29). As in the Waterloo quarry, an argillaceous, greenish gray lime mudstone (~ 4 feet thick) marks the boundary between the upper and lower St. Louis (fig. 29).

Ste. Genevieve Limestone Here, the Ste. Genevieve Limestone is characterized by fine-grained, lenticular, cross-bedded, partly arenaceous, oolitic grainstone (fig. 31). Lime mudstone and dolomite are also present within the Ste. Genevieve. Several shaley beds containing well-developed oncolites occur in the lower part of the Ste. Genevieve and may represent the transgressive facies deposited following the development of the upper St. Louis unconformity.

The conodont data of Rexroad and Collinson (1963) and additional conodont data collected during this study indicate that the contact between the St. Louis and Ste. Genevieve Limestones lies immediately above the "Lost River Chert" zone, a bryozoan-rich lime mudstone, wackestone, and chert. The last appearance of the conodont *Synclydognathus geminus* marks the top of the "Lost River Chert" zone (Norby and Lasemi 1999).

The oolitic facies of the Ste. Genevieve Limestone has been one of the most prolific hydrocarbon reservoirs in the Illinois Basin. In many areas in the subsurface, these grainstones are also underlain by a sucrosic dolomite that produces oil in some fields (Choquette and Steinen 1980).

Stop 5: Hickman Creek—*Hannes E. Leetaru*

Approximately the SW SW Sec. 32, T1N, R9W; Columbia 7.5-minute quadrangle, St. Clair County, Illinois (fig. 32)

The sandstone at the waterfall at Hickman Creek (fig. 33) has been interpreted to be either the Aux Vases Sandstone (Weller 1914) or the basal Pennsylvanian (Joseph A. Devera, ISGS, personal communication, 1998). Sandstones in both formations were deposited in similar environments and cannot be differentiated without biostratigraphic control. If this unit is the Aux Vases, then it is one of the most northern outcrops of the Aux Vases. The exposed sandstone has an erosional unconformity at both its top and base. The top of the sandstone is bounded by a 4-foot-thick, cross-bedded limestone pebble conglomerate. Clasts in this pebble conglomerate range up to 6 inches in diameter and are oriented preferentially with the flow direction.

Stop 6: Alby Quarry—*Zakaria Lasemi and Rodney D. Norby*

NE Sec. 11, T5N, R11W, Alton 7.5-minute quadrangle, Madison Co., Illinois (fig. 34)

The upper part of the Warsaw Formation and the Salem, lower St. Louis, upper St. Louis, and Ste. Genevieve Limestones are exposed in this quarry (fig. 35). The Warsaw–Salem boundary is marked by a heavily burrowed surface (fig. 36A) with abundant semi-vertical burrows (some U-shaped).

The Salem is relatively thin here, but shoaling-upward cycles are still present. A prominent unconformity characterized by a shaley, brecciated and conglomeratic, cherty, sandy limestone marks the Salem–St. Louis boundary (fig. 36B). This unconformity occurs a few feet above the highest Salem grainstone and is equivalent to the unconformity we have seen at this horizon throughout the St. Louis metro area.

The lower St. Louis Limestone lithology is generally similar to that seen at Casper Stolle Quarry (Stop 4). Here, a major brecciated unit occurs in the uppermost interval of the lower St. Louis (fig. 35). The breccia contains clasts ranging in size from gravel and pebbles to boulders several feet across (fig. 37). The matrix is greenish gray, argillaceous, and silty limestone. The origin of the breccia has been related to dissolution of gypsum or anhydrite (Collinson et al. 1954). The timing of the dissolution event is not clear, but it has been suggested that it may have occurred as a result of exposure to groundwater prior to deposition of the overlying beds (Collinson et al. 1954). This scenario is likely considering the very shallow marine setting (intertidal–supratidal) in which the lower St. Louis was deposited.

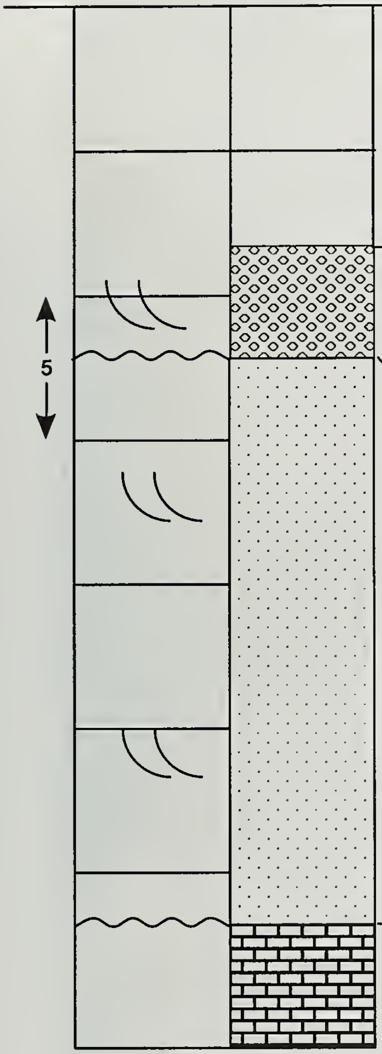
As at other stops, the upper St. Louis facies here is a bioclastic wackestone and packstone with some lime mudstone, grainstone, and dolomite. The lower–upper St. Louis boundary is marked

Figure 32 Location map of the Aux Vases Sandstone at Hickman Creek (Stop 5), approximately the SW SW Sec. 32, T1N, R9W; Columbia and Millstadt 7.5-minute quadrangles, St. Clair County, Illinois.

by a greenish gray, argillaceous limestone (fig. 35) similar to those at Stops 2, 4, and 7. The "Lost River Chert" zone is very thin here and consists of only a single chert bed; the bryozoan-rich lime mudstone to wackestone appears to be absent in this section. The "Lost River Chert" zone is overlain by an oncolitic bed similar to those at Stops 4 and 7. The overlying Ste. Genevieve Limestone, which is mostly inaccessible, consists of oolitic grainstone interbedded with lime mudstone and bioclastic wackestone.

Measured Section/well: Hickman Creek
Stratigraphic Interval: Aux Vases Sandstone
Location: Clair County, Sec. 32 T1N R9W
Logged by: HEL, SW
Date: 11/24/98

Depth (ft) | Structure | Lithology 0% 100%



Description	Interpretation
Shale and sandstone along floor of stream bed.	Yankeetown Formation
Limestone pebble conglomerate ranging from sand to cobble sized clasts. Clasts are oriented preferentially with the flow direction. Strata is cross bedded. Contact with lower sandstone is sharp.	Limestone clasts are eroded from the Ste. Genevieve Limestone. The Ste. Genevieve would be exposed in the interfluve areas.
Sandstone is massively bedded with faint cross-bedding; the outcrop is covered by moss. The sandstone is a fine- to medium-grained, well-sorted quartz arenite.	The Aux Vases Sandstone in this outcrop is interpreted to be part of an incised valley fill.
Sharp contact of sandstone with limestone. Limestone contains ooids, peloids, and crinoidal fragments.	Top of the Ste. Genevieve Limestone.

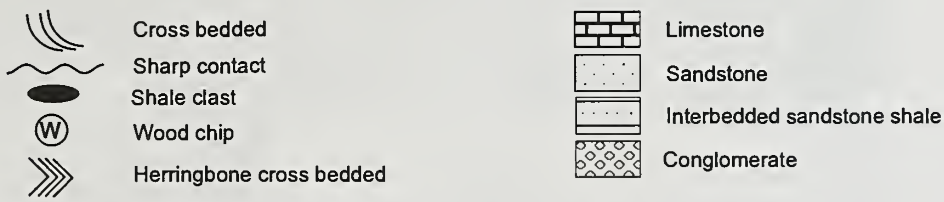


Figure 33 Measured section for the Hickman Creek outcrop in St. Clair County, Illinois (modified from Leetaru 1997).

Figure 34 Location map of Alby Quarry (Stop 6) and Alton bluff section (Stops 7 and 8). Alby Quarry, NE Sec. 11, T5N, R10W, Alton 7.5-minute quadrangle, Madison Co., Illinois. The Alton bluff section begins in NW NE NW Sec. 14, T5N, R10W, behind the ConAgra plant along IL 100 and continues west into NE NW NW of Sec. 14 and into SW SW Sec. 11. Additional section present in SE Sec. 10, T5N, R10W, Alton 7.5-minute quadrangle, Madison County, Illinois.

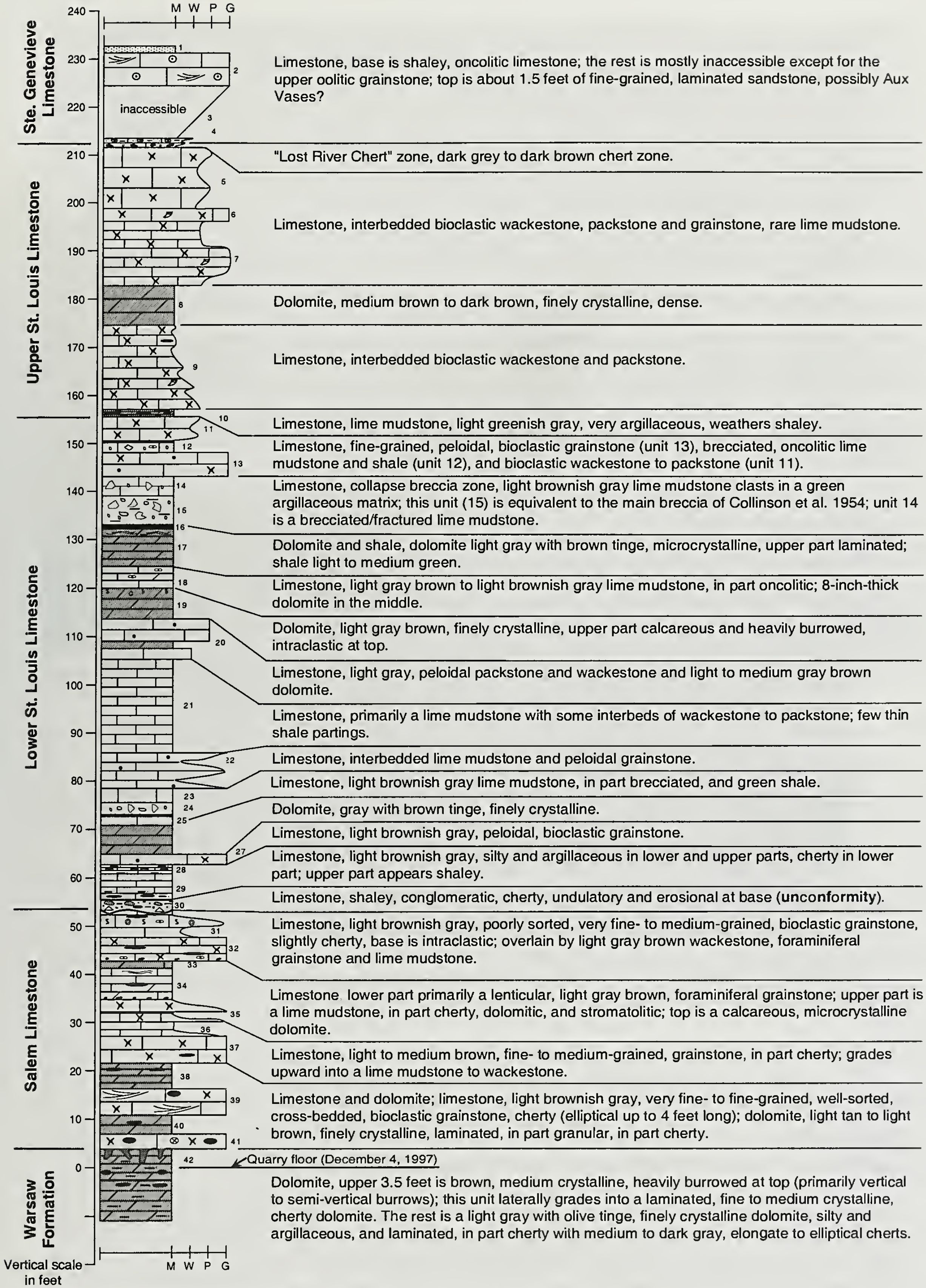


Figure 35 Stratigraphic column of Alby Quarry. See figure 20b for key.

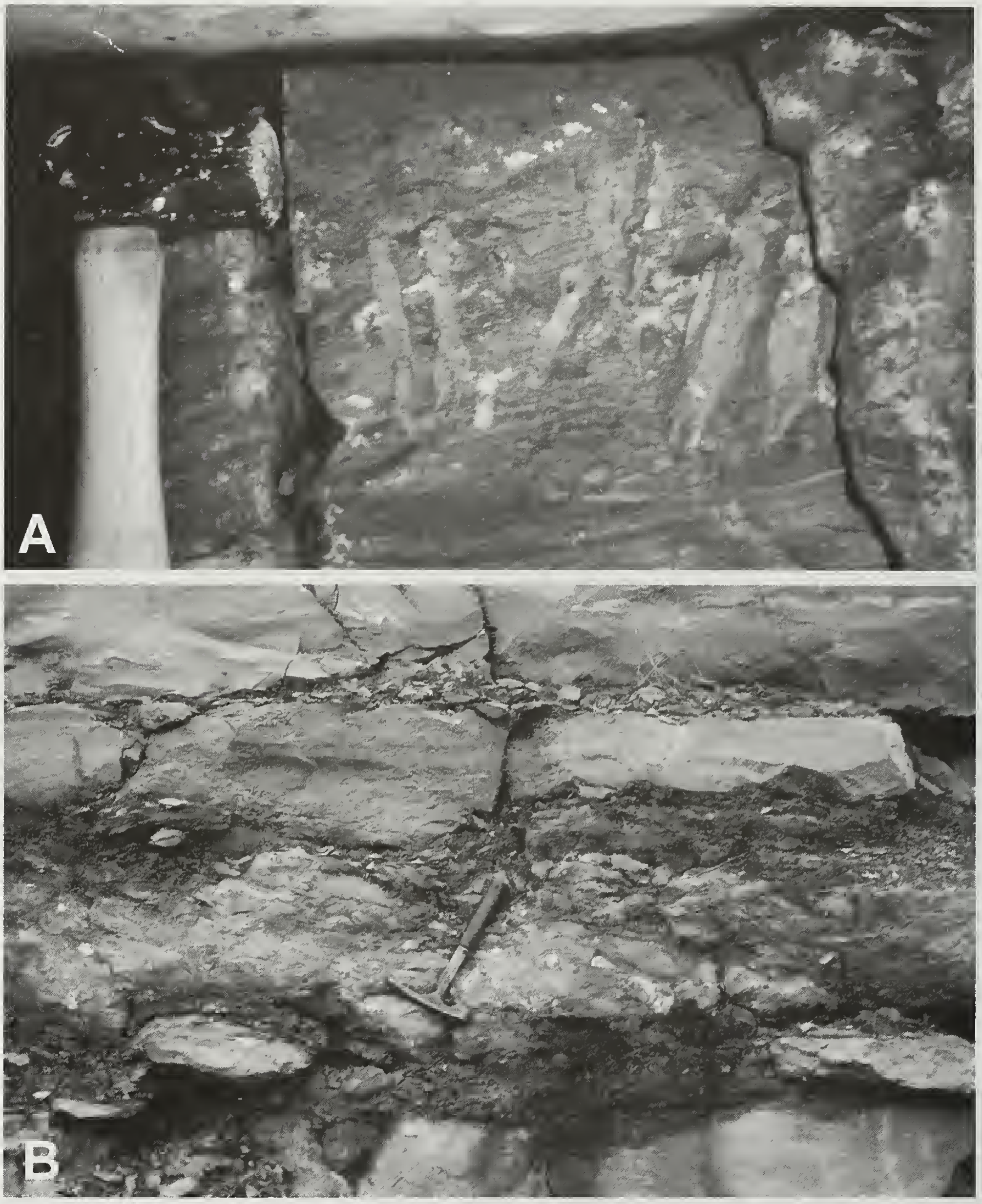


Figure 36 Features of the Salem Limestone in Alby Quarry. (A) Burrowed interval at the Warsaw–Salem boundary; note U-shaped burrow. (B) Unconformity at the Salem–St. Louis boundary. Hammers for scale.

Stop 7: Alton Bluff Section—*Rodney D. Norby and Zakaria Lasemi*

NW NE NW Sec. 14, NE NW NW Sec. 14, and SW SW Sec. 11, T5N, R10W, additional section present in SE Sec. 10, T5N, R10W; Alton 7.5-minute quadrangle, Madison Co., Illinois (fig. 34)

This bluff section (fig. 38) was first described in detail by Collinson et al. (1954), and their description has been used in a modified form in several later guidebooks (e.g., Collinson and Swann 1958). No specific exposure was ever designated as the type section for the St. Louis Limestone. Thompson (1986) indicated that the Alton bluff section and exposures to the northwest of Alton are the best, most complete exposures of the St. Louis Limestone in the St. Louis metro area. At

Figure 37 Collapsed breccia in the upper part of the lower St. Louis Limestone, Alby Quarry. Vertical dimension is approximately 3 feet.

this section, we will observe the uppermost beds of the lower St. Louis Limestone, the upper St. Louis, and the Ste. Genevieve Limestone (fig. 39A) and discuss the beds previously termed "transition beds." Unfortunately, the beds of the Ste. Genevieve are inaccessible, as are some beds in the upper St. Louis. Most of the beds of the lower St. Louis can be examined in various locations along the bluff to the northwest.

The upper part of the lower St. Louis is present as units A and B of Collinson et al. (1954) at the west end of the exposure (fig. 38). The "main breccia" (unit A) is a highly brecciated interval consisting of angular pebbles to boulders, primarily of lime mudstone in a silty, argillaceous limestone matrix. The possible origins were discussed at Stop 6. Unit B is another brecciated bed, apparently an overlying bed that only partially collapsed. Unit C is a greenish gray, shale limestone that we have identified as regionally marking the break between the lower and upper St. Louis Limestone.

The conodont data of Rexroad and Collinson (1963) and notes in our files suggest that *Taphrognathus varians* and some transitional specimens between *Taphrognathus* and *Cavusgnathus* occur in units A and B. These species are characteristic of the lower St. Louis and beds near the contact between the lower and upper St. Louis. Conodonts indicative of the upper St. Louis include *Synclydognathus geminus* and *Cavusgnathus unicornis* (key species in the unrevised *Apatognathus scalenus–Cavusgnathus* Assemblage Zone of Rexroad and Collinson 1963). These latter species first appear in units C and D, although a few primitive forms are mixed in with some of the older fauna in the upper breccia or unit B (probably due to the process of brecciation). These conodont data correspond well with the boundary between the lower and upper St. Louis that we pick at the base of unit C.

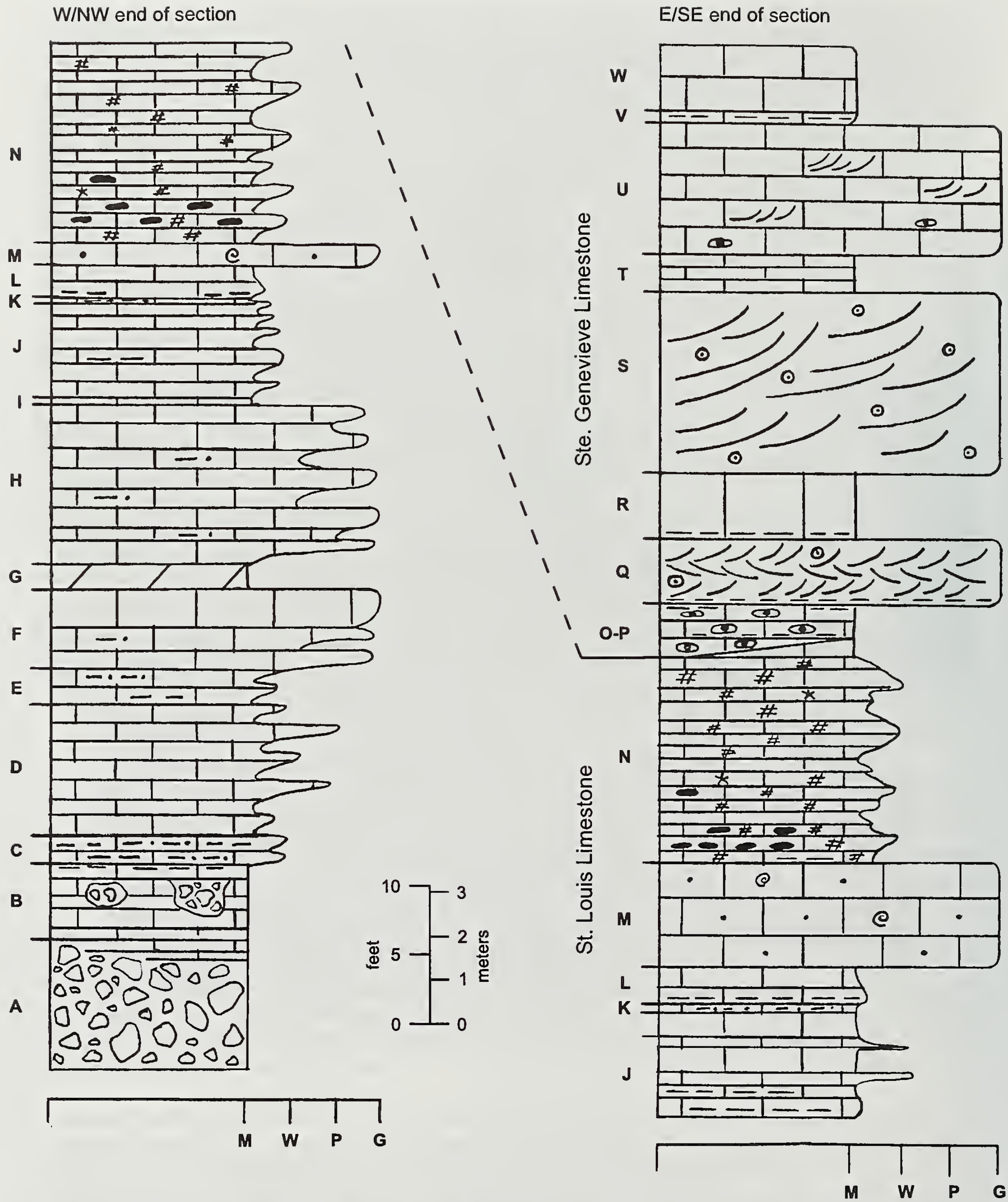


Figure 38a Stratigraphic columns for the northwest and southeast end of the Alton bluff section. See figure 20b for key.

STE. GENEVIEVE LIMESTONE

Beds T, U, V, W. Limestone, variable, inaccessible or difficult to access, thin-bedded to slightly cross-bedded, partly algal, some shaly.

Bed S. **"Sandy oolite,"** grainstone, oolitic, cross-bedded, massive.

Bed R. **"White bed,"** lime mudstone to wackestone, cream to light grayish brown, weathers nearly white, thin shale parting at base.

Bed Q. **"Chevron bed,"** limestone, appears oolitic, arenaceous, bimodal cross-beds; basal part of unit is an oncolitic conglomerate; unit thickens toward Mississippi Lime's sand piles.

Bed P. **"Algal conglomerate,"** lime mudstone to wackestone, argillaceous, with numerous algal oncolites ranging in size from a few millimeters up to 30 centimeters in diameter, light brownish gray, often with green tinge; upper 15 cm is very shaly with small oncolites, basal surface irregular.

Bed O. **"Little white bed,"** grainstone?, silty, algal, lenticular, erosional base, fills cracks in Bed N, not present at southeast end of exposure.

ST. LOUIS LIMESTONE

Upper St. Louis

Bed N. **"Bryozoan beds and chert marker,"** wackestone to lime mudstone, light grayish brown, very fine grained, bioclastic, bryozoan-rich particularly in lower part, sporadic chert in lower part, one particular bed near base is considered to represent part of the Lost River Chert Bed; thin bedded, generally 10-20 cm, some thinner, lower contact undulatory.

Bed M. **"Lower oolite,"** grainstone, light brownish gray to light gray fresh, weathers very light gray, peloidal, fine grained, cross-bedded, cross-bed sets range between 1.0-2.5 feet, upper contact undulatory. Collinson et al. (1954, p. 18) described this as a slightly sandy oolite (we did not note any true ooids).

Bed L. **"Two beds,"** lime mudstone with some fine- to coarse-grained bioclastic grainstone, two distinct beds, slight shale parting at base.

Bed K. Limestone, very silty, grading downward to prominent shale break.

Bed J. Lime mudstone with some bioclastic grainstone, slightly silty, thin-bedded, several shale streaks.

Bed I. **"Five-inch bed,"** limestone bed between two distinct <u>shale</u> partings.

Bed H. Lime mudstone with some grainstone, silty.

Bed G. **"Dark band,"** dolomite, silty, medium brownish gray, thickness varies from one to twenty-four inches.

Bed F. Lime mudstone to grainstone, slightly silty.

Bed E. **"Pseudoconcretion bed,"** limestone, silty, shaly, with numerous large oval 6-inch to 3-foot silty dolomite pseudo-concretions.

Bed D. Lime mudstone, some wackestone and grainstone, fossiliferous.

Bed C. Wackestone primarily, but variable lithology, greenish gray, shaly, silty, argillaceous, and fossiliferous.

Lower St. Louis

Bed B. **"Upper breccia,"** lime mudstone with some grainstone, variable in lithology and partially brecciated.

Bed A. **"Main breccia,"** limestone, highly brecciated with angular clasts (some boulder sized) of lime mudstone to grainstone in silty grainstone.

Figure 38b Key to figure 38a. Lettered beds and names in quotes were used by Collinson et al. (1954) and are given for comparison purposes. Most of the lithologic information is from Collinson et al. (1954); updated notes on beds C and M–S are from this guidebook.

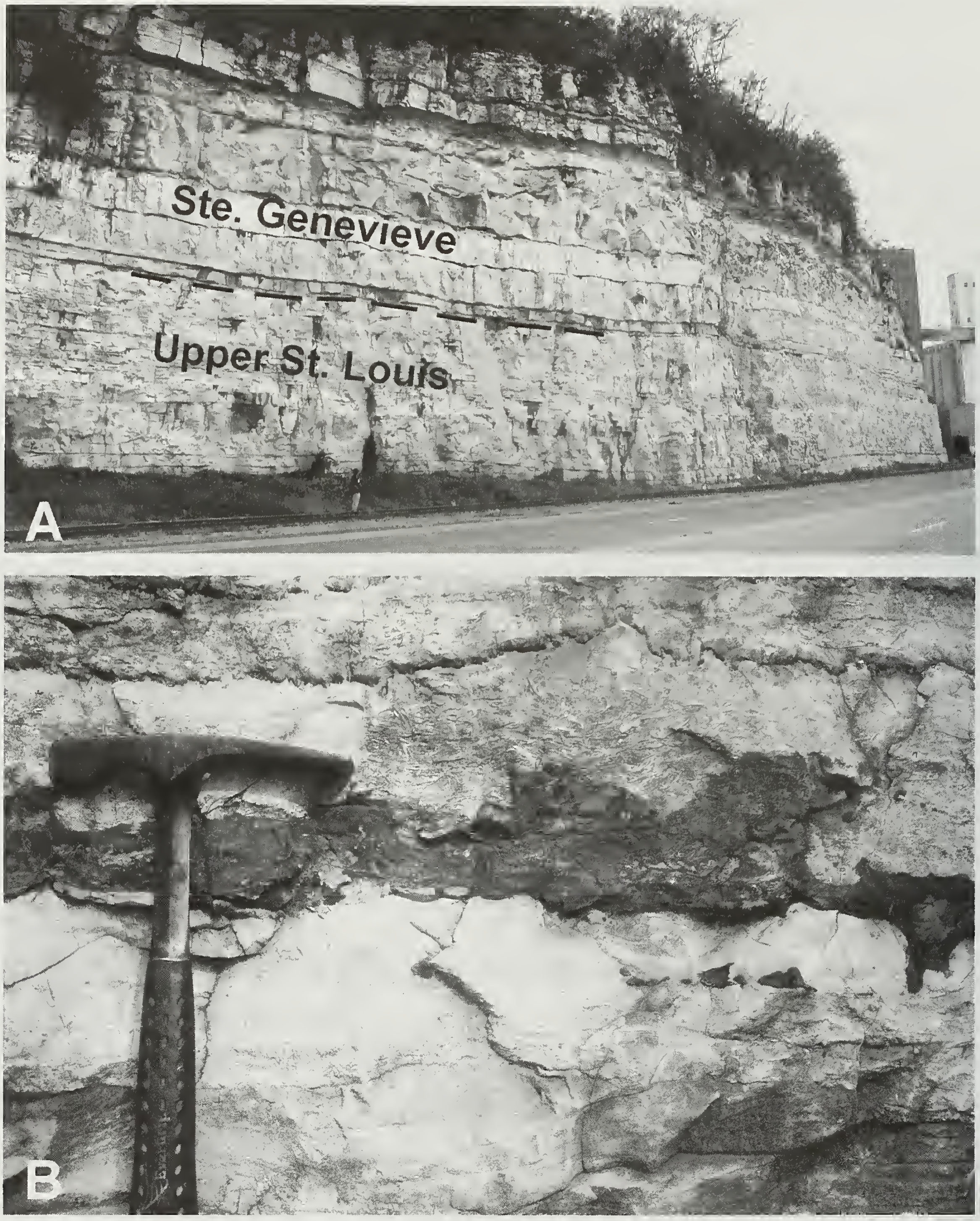


Figure 39 Features of the Alton bluff section. (A) Overall view showing upper St. Louis and Ste. Genevieve Limestones from beds J–W on the southeast end of section (fig. 38). Person for scale. (B) Close view showing chert bed (dark gray) in the bryozoan-rich "Lost River Chert" zone in the upper St. Louis. Hammer for scale.

The St. Louis-Ste. Genevieve "transition zone" (Collinson et al. 1954) was used particularly at this section because certain lithologic and faunal attributes appeared to be mixed, which makes identification of a formational boundary difficult. The base of the "transition zone" was drawn at the base of unit M (fig. 38), which Collinson et al. (1954) described as an oolite and considered to indicate Ste. Genevieve sedimentation. Our samples and thin sections did not show any ooids, and most of the rock is a peloidal, bioclastic grainstone, common in the upper St. Louis. In units D, H, and N, the crinoid or stems of *Platycrinites penicillus* were noted by Collinson et al. (1954). These are generally considered a guide to the Ste. Genevieve, but they have also been noted in the St. Louis Limestone in the Ste. Genevieve, Missouri, area (Weller and St. Clair 1928) and possibly in the Salem (Weller et al. 1948). Stems of *Platycrinites* sp. are also present in undisputed (based on conodont data) upper St. Louis strata at Waterloo quarry (Stop 2). Therefore, certain fossils and the general lithology may not be good indicators for identifying the St. Louis–Ste. Genevieve boundary.

The key lithologic features that we use to separate the St. Louis from the Ste. Genevieve Limestone in this section include the thinly bedded, bryozoan-rich lime mudstone and wackestone of the "Lost River Chert" zone (unit N; fig. 39B). The Ste. Genevieve contains well developed oolitic grainstone. Locally, oncolitic algal beds appear to represent earliest Ste. Genevieve deposition. These features are similar to those present at Casper Stolle Quarry (Stop 4).

The conodont *Synclydognathus geminus* also disappears in the upper part of unit N, which reinforces our determination of the boundary. *S. geminus* is the key conodont in the *Apatognathus scalenus–Cavusgnathus* Assemblage Zone of Rexroad and Collinson (1963) and Collinson et al. (1971) and has its last appearance at or very close to the top of the St. Louis in Illinois, Indiana, and eastern Missouri (Collinson et al. 1971). This corresponds to our placement of the St. Louis–Ste. Genevieve boundary between units N and O–P (fig. 38).

Collinson et al. (1954) noted deep fissures extending downward several feet into the top of unit N that were filled with material from unit P (unit O is a thin local unit that is not always present). Similar fissures were also reported at the top of the St. Louis in Ste. Genevieve County, Missouri (Weller and St. Clair 1928), where the upper St. Louis has been truncated and a prominent conglomeratic horizon occurs at the St. Louis–Ste. Genevieve boundary. A comparison of this interval with that in Alby Quarry indicates that unit N is thicker here, which suggests that some beds may have been eroded away at the top of the St. Louis before the deposition of the algal beds (units O–P). The fissures suggest that subaerial exposure and dissolution due to karstification may have occurred at the end of St. Louis deposition. Due to inaccessibility, the fissures noted by Collinson et al. (1954) cannot be seen at this location. The abrupt change from thinly bedded normal marine beds (unit N) to shaley and sandy oncolitic beds of unit P is significant. It probably represents the transgressive facies of the lower part of the Ste. Genevieve.

Stop 8: Faulting in the Alton Bluff Section—*Joseph A. Devera and F. Brett Denny*

NW NE NW Sec. 14, NE NW NW Sec. 14, and SW SW Sec. 11, T5N, R10W; additional section present in SE Sec. 10, T5N, R10W; Alton 7.5-minute quadrangle, Madison Co., Illinois (fig. 34)

A strike-slip fault zone occurs in an old quarried bluff on the property of the Abbott Machine Company (SW SW Sec. 11, T5N, R10W) on the Mississippi River at Alton, Illinois (fig. 40). Numerous vertical and undulating vertical fractures occur on the highwall within the St. Louis Limestone and the lower part of the Ste. Genevieve Limestone. The fractures strike N10°E to N60°E. Well-developed horizontal slickensides, mullions, brecciation, and large calcite veins are present on fault surfaces. Offsets of 6 to 12 inches are observed on the bedding along these structures. Downstepping of bedding to the east at a horizontal distance of 200 feet yielded offsets of about 6 feet. Both right-lateral and left-lateral movements were found on the highwall. The largest fault appears

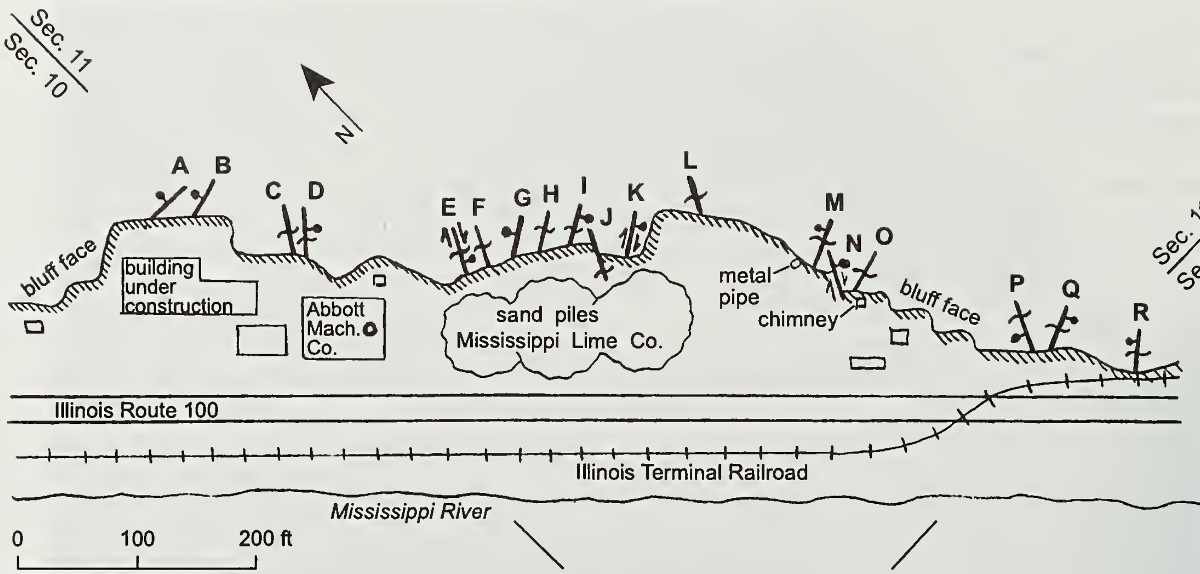


Figure 40 Map of the Alton bluff section on the west side of Alton, Illinois, showing faults in the St. Louis Limestone, Sec. 11, T5N, R10W, Alton 7.5-minute quadrangle, Madison County, Illinois. Map by W.J. Nelson with J.A. Devera, October 20, 1997.

to be a right-lateral fault that strikes N10°E. Some of these faults were originally reported in the guidebook by Collinson et al. (1954).

Along the same highwall traversing east, a yellowish crinoidal limestone marker bed “steps down” to the east about 5 feet between three faults over a distance of 40 feet. The dip of the marker bed is 4° to the east with a northeast strike. The first two strike-slip faults also dip to the east about 70°; the third fault is vertical. Farther east of the third fault, the marker bed is displaced below the quarry floor. Continuing east along the highwall, more vertical strike-slip faults with mullions, clay gouge, and breccia are common; however, the dip on the beds reverses to the west about 4° and strikes northeast. This is evidence for extension in the small area near the Abbott Machine Company.

Harrison (1993) reported that calcite mineral growth along these faults indicates that the N45°– 70°E faults have a left-lateral sense of slip, whereas the N5°–10°E faults show a right-lateral sense of slip. Harrison (1993) suggested that the area along the bluff shows small-scale positive flower structures that indicate transpression; small areas such as those by the Abbott Machine Company, however, may be local extensional adjustments that look like small-scale negative flower structures.

The faults trending N45°–55°E in the bluffs southwest of Alton, Illinois, are through-going faults that are also observed in an abandoned quarry ⅓ mile to the northeast of the bluffs in the city of Alton. These faults are strike-slip faults that also appear to have a left-lateral sense of slip. These N45° to 55°E faults parallel and are on strike with the St. Charles magnetic anomaly (Harrison 1993).

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STOP 6
Alby Quarry
STOP 7,8
Alton Bluff Section
STOP 4
Casper Stolle Quarry
STOP 5
Hickman Creek
STOP 1
Columbia Roadcut
STOP 2, 3
Waterloo Quarry
and Rock Creek
Ste. Genevieve Area
MADISON
ST CLAIR
MONROE
RANDOLPH
EAST ST LOUIS
MISSISSIPPI
PERE MARQUETTE STATE PARK
MARK TWAIN N W R
U S MIL RES
HOLTEN STATE PARK
SCOTT AFB
DAM NO 27
LOCK NO 27
Nutwood
Rosedale
Otterville
McClusky
Dow
Newbern
Grafton
Chautauqua
Elsah
Delhi
New Delhi
Brighton
Woodburn
Godfrey
Melville
Fosterburg
Dorsey
Moro
Bethalto
Alton
East Alton
Wood River
Roxana
Hartford
Dorchester
Wilsonville
Bunker Hill
Sawyerville
White City
Mt Olive
Walshville
Staunton
Williamson
Livingston
New Douglas
Prairietown
Midway
Worden
Carpenter
Hamel
Alhambra
Old Ripley
Panama
Sorento
Edwardsville
Fruit
Grantfork
Marine
Kuhn
Poag
Mitchell
Pontoon Beach
Granite City
Madison
Venice
Glen Carbon
Maryville
Troy
Highland
Pierron
Pocaho
Jamestown
St Jacob
St Rose
Collinsville
St Morgan
Caseyville
Washington Park
Lebanon
O'Fallon
Summerfield
Trenton
Aviston
Fairview Heights
Centreville
Shiloh
Swansea
East Carondelet
Dupo
Sugarloaf Heights
Rentchler
Mascoutah
New Baden
Albers
New Memphis
Damiansville
Venedy Station
Okawville
Columbia
New Hanover
Freeburg
Smithton
Floraville
Paderborn
Fayetteville
St Libory
Stone Church
Merrimac
Fountain
Waterloo
New Athens
Darmstadt
Lively Grove
Elkton
Valmeyer
Wartburg
Hecker
Lenzburg
Harrisonville
Burksville
Monroe City
Maeystown
Marissa
Clarmin
Oakdale
Red Bud
Grigg
Baldwin
Tilden
Coulterville
Fults
Renault
Ames
Ruma
Houston
Swanwick
Kidd
Eden
Preston
Walsh
Sparta
Prairie du Rocher
Evansville
Schuline
Modoc
Blair
Jamestown
Roots
Ellis Grove
Percy
Cutler
Steeleville
Reily Lake
Ft Gage
Bremen
Welge
Willisville
Kaskaskia
Menard
Chester
Shiloh Hill
Campbell
0
10
20 mi
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30 km
N